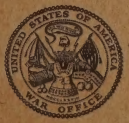
DEPARTMENT OF THE ARMY TECHNICAL MANUAL

DEPARTMENT OF THE AIR FORCE TECHNICAL ORDER

TM 10-1690A
TO 19-75CBAE-13

INDUSTRIAL MOTIVE POWER STORAGE BATTERIES FOR MATERIALS HANDLING EQUIPMENT



DEPARTMENTS OF THE ARMY AND THE AIR FORCE

JULY 1954

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TM 10–1690A/TO 19–75CBAE–13

TECHNICAL MANUAL
No. 10–1690A
TECHNICAL ORDER
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DEPARTMENTS OF THE ARMY AND
THE AIR FORCE

WASHINGTON 25, D. C., *29 July 1954*

INDUSTRIAL MOTIVE POWER STORAGE BATTERIES FOR MATERIALS HANDLING EQUIPMENT

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PART ONE

LEAD-ACID STORAGE BATTERIES

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1. Scope

Part one of this manual contains information concerning the theory, operation, charging, and maintenance of 18-cell, 36-volt, lead-acid storage batteries used for motive power in electric-powered forklift trucks, warehouse tractors, and industrial cranes. Table I identifies and itemizes characteristics for all lead-acid storage batteries described in this manual.

Table I. Lead-Acid Storage Batteries for Materials Handling Equipment.

Manufacturer	Quartermaster stock number	Ampere-hour capacity	Cells	Plates	Model number
C & D Batteries, Inc					
	17–B–8654	360	18	13	18CDS13
	17–B–8665	540	18	19	18CDS19
	17–B–8678	720	18	25	18CDS25
Electric Storage Battery Company (Exide)					
	17–B–8650	300	18	13	18TLM13
	17–B–8660	450	18	19	18TLM19
	17–B–8670	600	18	25	18TLM25
Gould-National Batteries, Inc					
	17–B–8652	330	18	13	18XLZ13
	17–B–8662	495	18	19	18XLZ19
	17–B–8672	660	18	25	18XLZ25

2. Forms, Records, and Reports

The following forms will be used by personnel responsible for the receipt, storage, operation, charging, and maintenance of lead-acid storage batteries.

a. Report of Damaged or Improper Shipment. DD Form 6, Report of Damaged or Improper Shipment, will be filled out and forwarded as prescribed in SR 745–45–5 whenever batteries are received damaged or improperly prepared for shipment.

b. Unsatisfactory Equipment Report. DA Form 468, Unsatisfactory Equipment Report, will be filled out and forwarded to the Office of the Quartermaster General, Washington 25, D. C., whenever common deficiencies or malfunctions are noted in new batteries. The form should also be used to report suggestions for improvement in design and maintenance of equipment, safety and efficiency of operation, and application of preservatives; unsatisfactory design; defects, failures, or malfunctions; and defects traceable to absence or inadequacy of spare parts and related equipment. In such cases DA Form 468 should be prepared in ac-

cordance with instructions contained in SR 700–45–5 and submitted to the Office of the Quartermaster General, Washington 25, D. C.

c. DA Form 10–161 (Monthly Storage Battery Record). The Monthly Storage Battery Record is a form for recording the services performed on lead-acid and nickel-iron-alkaline storage batteries. The record should be prepared and maintained by the using organization and should accompany the battery at all times.

Section II. DESCRIPTION

3. Battery

Motive-power lead-acid storage batteries for electric-powered trucks, tractors, and cranes consist essentially of 18 cells, a steel tray into which the cells are assembled, a battery connector, and other components necessary to secure and protect the cells and provide necessary electrical interconnections (fig. 1).

a. Cell Arrangement. The 18 cells that comprise the energy-generating components of the battery may be arranged differently for various types of batteries (figs. 2–4). Cells of all 36-volt batteries are connected in series, however, to deliver the required voltage. Cells are normally assembled in 3 rows of 6 each. The battery is then identified by a series of numbers and letters that indicate the number of cells, the type of cells, and the number of plates per cell. The designation 18TLM19, for example, indi-

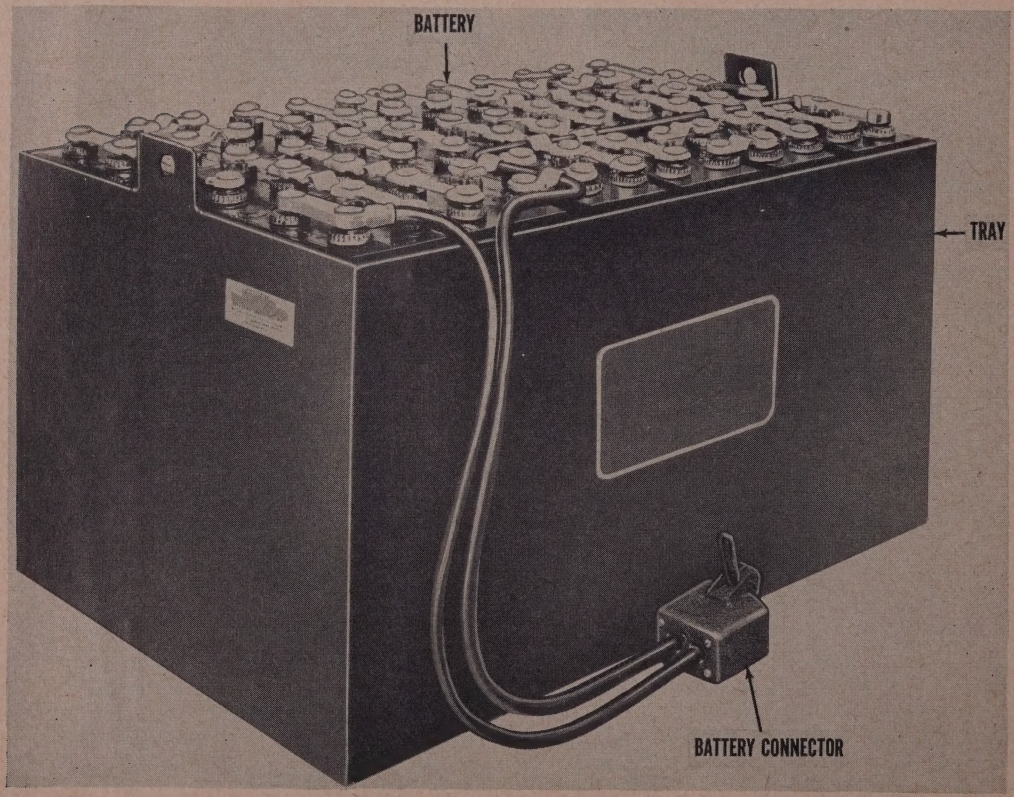


Figure 1. Lead-acid storage battery for motive-power service.

cates that the battery contains 18 cells of the TLM type with 19 plates per cell.

b. Tray Specifications. The battery tray in which cells are assembled is of steel construction. Tray sizes and weights for various types of lead-acid batteries are given in table II.

Table II. Specifications for Lead-Acid Batteries in Steel Trays

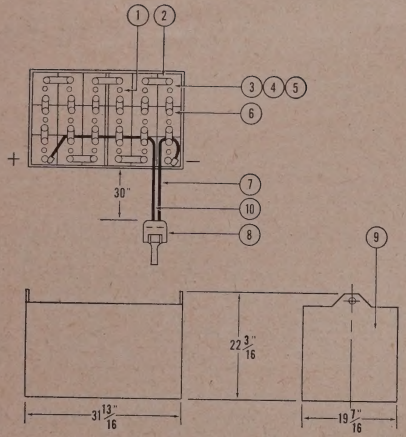
Battery and model numbers	Length	Width	Height	Weight			
				Net		Packed	
				Wet	Dry	Wet	Dry
	Inches	Inches	Inches	Pounds	Pounds	Pounds	Pounds
C & D:							
18CDS13	31 5/16	19 7/16	22 5/16	1,550	1,295	1,740	1,485
18CDS19	38 3/4	23 1/8	22 5/16	2,156	1,780	2,420	2,044
18CDS25	38 3/4	29 11/16	22 5/16	2,862	2,367	3,217	2,722
Exide:							
18TLM13	31 5/8	19 5/8	21 7/8	1,278	1,048	1,470	1,241
18TLM19	38 3/4	23 1/8	21 7/8	1,872	1,526	2,153	1,811
18TLM25	38 3/4	29 7/8	21 7/8	2,412	1,948	2,774	2,311
Gould:							
18XLZ13	31 3/8	19 5/8	22 1/2	1,440	1,210	1,590	1,360
18XLZ19	38 3/4	23 1/8	22 1/2	2,090	1,730	2,300	1,940
18XLZ25	38 3/4	29 7/8	22 1/2	2,700	2,240	2,970	2,510

c. Connector Arrangement. Connection between cells is made by intercell connectors (fig. 5). These may be heavily leaded, flexible copper straps or solid connectors of lead-antimony alloy. Intercell connectors may be arranged differently for various types of batteries (figs. 2–4). Total energy from the battery of cells is drawn off by cable. On all 36-volt lead-acid batteries, the cable to the locking or mounting half of the standard battery connector (fig. 1) extends 30 inches beyond the end of the tray.

4. Cell

The cell (figs. 6 and 7) is the fundamental unit of the battery. It consists of an acid-resistant, hard-rubber jar, housing a cell element.

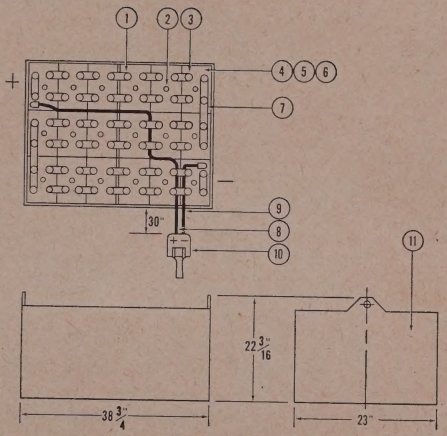
a. Element. The cell element consists of groups of positive and negative lead plates immersed in an electrolyte solution consisting of 38 percent sulphuric acid. In lead-acid batteries, the electrolyte solution causes electrochemical reactions within the cell element and serves as a carrier for the electric current produced as a result of these reactions. The electrolyte in a fully charged cell normally has a specific gravity of 1,280 at 77° F. As the cell operates, the specific gravity of the electrolyte solution decreases. Measurement of this specific gravity by means of a hydrometer indicates the state of charge of the cell; and, the reading of any one cell, known as a pilot cell, indicates the state of charge of the battery as a whole. The top of each cell is fitted with a cell cover of molded hard rubber or other acid-resistant material. The positive and negative terminal posts from the cell element fit through openings in the cover, and the cells are so placed that the positive terminal of one cell is adjacent to the negative terminal of the next. A vent and a fillercap, through which electrolyte solution may be added, are located in the center of the cover. On some batteries the cell covers are fastened to the terminal posts by seal nuts and gaskets; on others, lead bushings are molded into the cover and welded to the terminal posts. The molded-type cover cannot be installed on batteries previously equipped with the seal-nut-and-gasket type. The cell jar is constructed so that the cell element may be entirely surrounded by electrolyte solution. The element is prevented from contacting the bottom of the cell by means of ribs that also provide sediment spaces at the bottom of the cell to accommodate active material shed by the positive plates of the element during the normal life of the battery. Cell construction is shown in figures 8 and 9, and cell specifications are given in table III.



A 18CDS13

A. 18CDS13

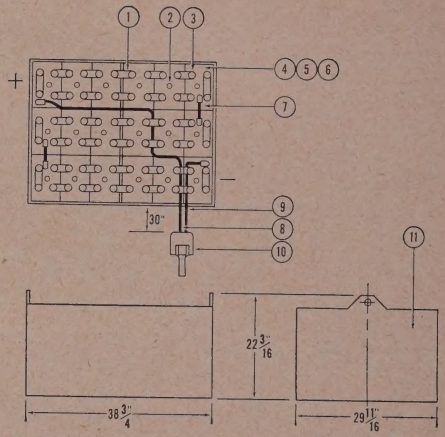
1 Vent plug
2 Intercell connector
3 Cell
4 Hard-rubber jar
5 Hard-rubber cover
6 Intercell connector
7 Negative terminal connector lead
8 Connector (locking half)
9 Steel tray
10 Positive terminal connector lead



B 18CDS19

B. 18CDS19

1 Intercell connector
2 Vent plug
3 Intercell connector
4 Cell
5 Hard-rubber jar
6 Hard-rubber cover
7 Intercell connector
8 Positive terminal connector lead
9 Negative terminal connector lead
10 Connector (locking half)
11 Steel tray

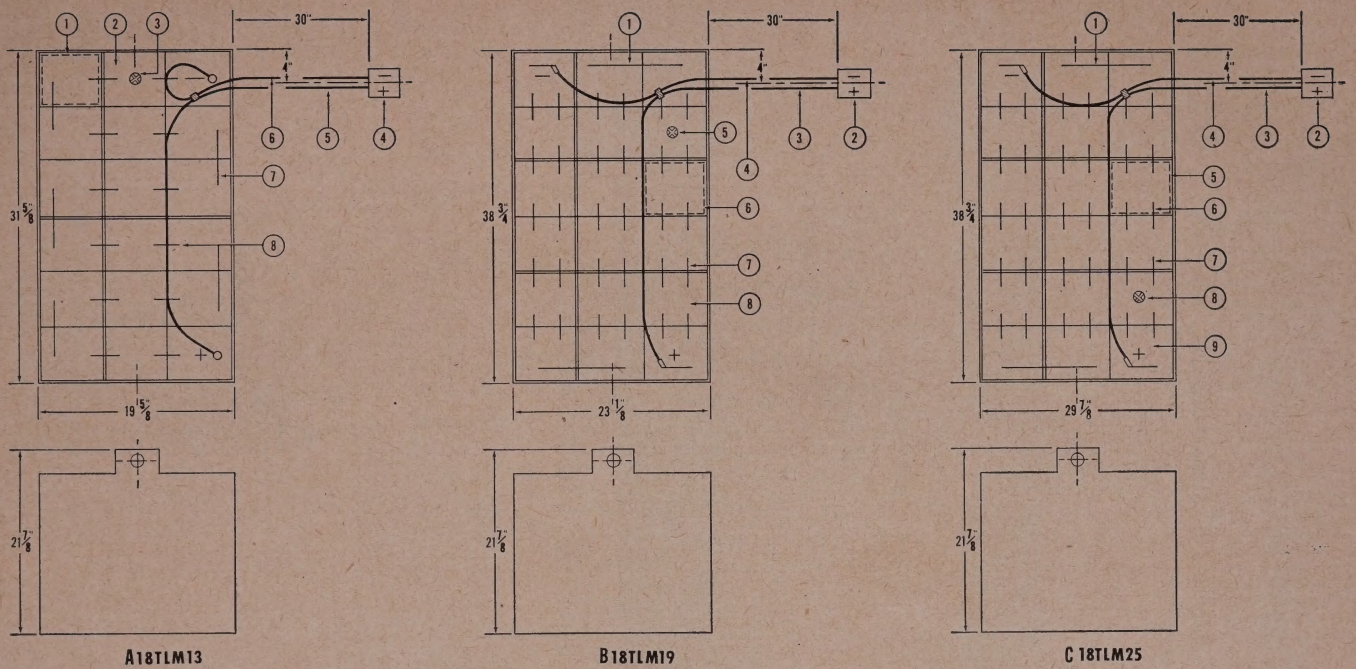


C 18CDS25

C. 18CDS25

1 Intercell connector
2 Vent plug
3 Intercell connector
4 Cell
5 Hard-rubber jar
6 Hard-rubber cover
7 Intercell connector
8 Positive terminal connector lead
9 Negative terminal connector lead
10 Connector (locking half)
11 Steel tray

Figure 2. Cell arrangements for C & D batteries.



A. 18TLM13

1 Hard-rubber jar
2 Hard-rubber cover
3 Vent plug
4 Connector (locking half)
5 Positive terminal connector lead
6 Negative terminal connector lead
7 Intercell connector
8 Intercell connector

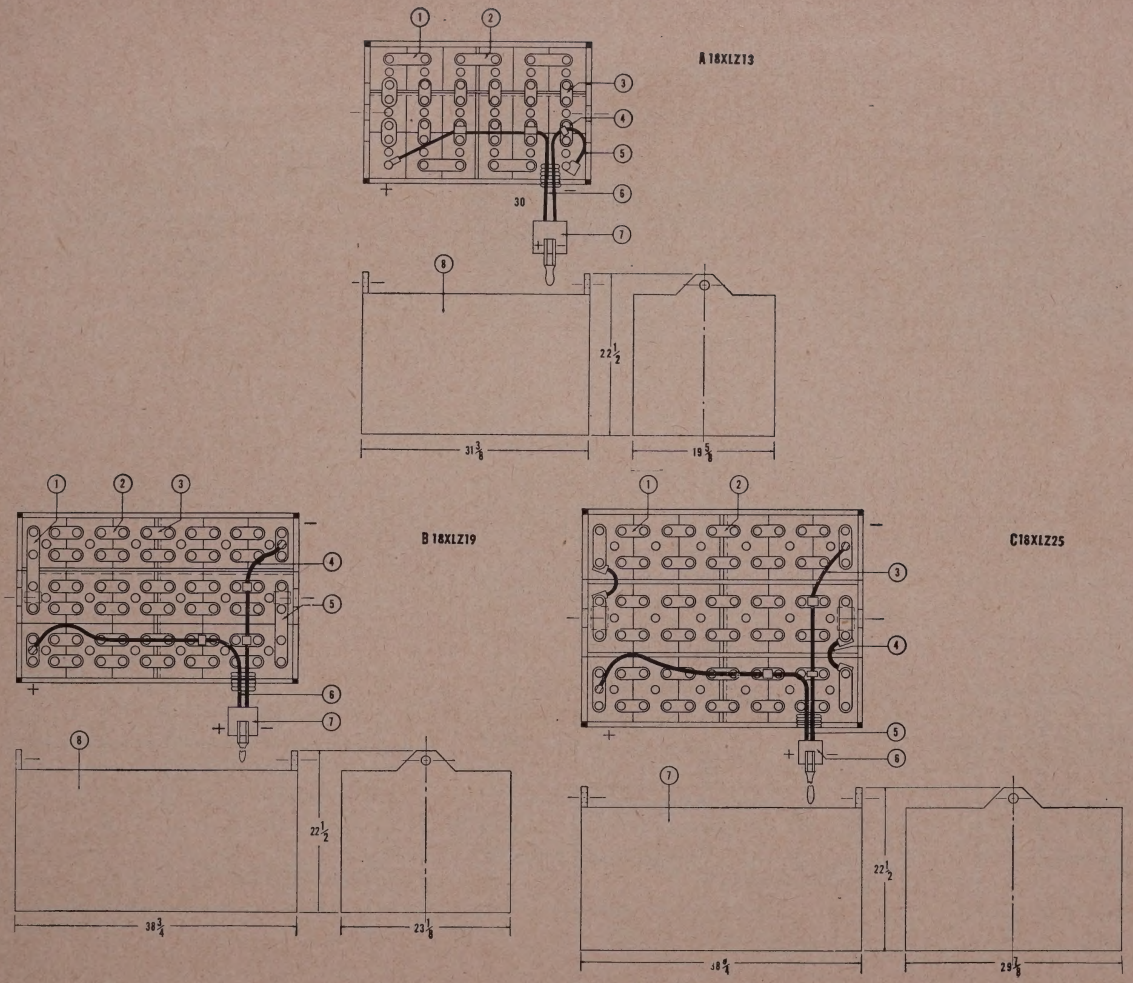
B. 18TLM19

1 Intercell connector
2 Connector (locking half)
3 Positive terminal connector lead
4 Negative terminal connector lead
5 Vent plug
6 Hard-rubber jar
7 Intercell connector
8 Hard-rubber cover

C. 18TLM25

1 Intercell connector
2 Connector (locking half)
3 Positive terminal connector lead
4 Negative terminal connector lead
5 Hard-rubber jar
6 Intercell connector
7 Intercell connector
8 Vent plug
9 Hard-rubber cover

Figure 3. Cell arrangement for Exide batteries.



A. 18XLZ13

1 Intercell connector
2 Intercell connector
3 Intercell connector
4 Intercell connector
5 Negative terminal connector lead
6 Positive terminal connector lead
7 Connector (locking half)
8 Steel tray

B. 18XLZ19

1 Intercell connector
2 Intercell connector
3 Intercell connector
4 Negative terminal connector lead
5 Intercell connector
6 Positive terminal connector lead
7 Connector (locking half)
8 Steel tray

C. 18XLZ25

1 Intercell connector
2 Intercell connector
3 Negative terminal connector lead
4 Intercell connector
5 Positive terminal connector lead
6 Connector (locking half)
7 Steel tray

Figure 4. Cell arrangement for Gould batteries.

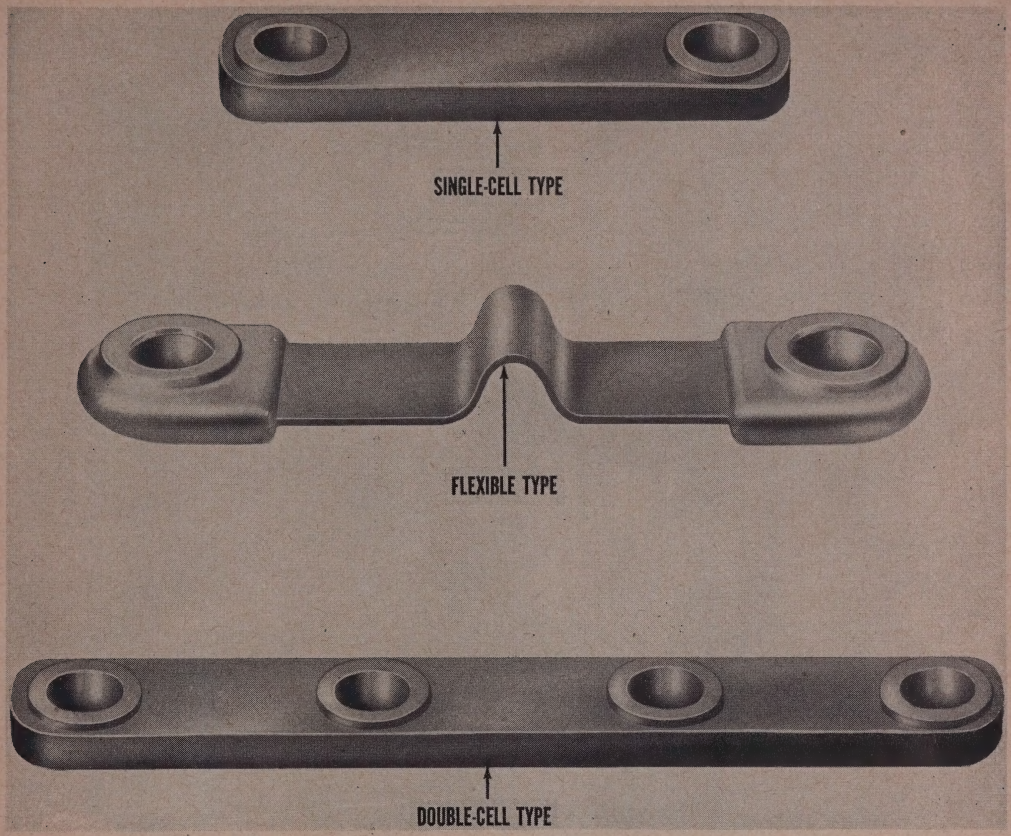


Figure 5. Intercell connectors.

Table III. Cell Specifications, Lead-Acid Batteries

Battery and model numbers	Cell dimensions			Cell weight			Electrolyte per cell
	Length	Width	Height [1]	Empty	Filled	Trayed [2]	
	Inches	Inches	Inches	Pounds	Pounds	Pounds	Pounds
C & D:							
18CDS13	5 1/8	6 1/4	20 3/4	59	72	86	12.5
18CDS19	7 3/8	6 1/4	20 3/4	87	106	120	18.8
18CDS25	9 5/8	6 1/4	20 3/4	112	140	159	24.8
Exide:							
18TLM13	5 1/16	6 1/16	20 3/4	58	71	71	12.7
18TLM19	7 3/8	6 1/4	20 3/4	86	104	104	19.0
18TLM25	9 5/8	6 1/4	20 3/4	108	134	134	25.7
Gould:							
18XLZ13	5 1/16	6 1/16	20 3/4	59	72	80	13
18XLZ19	7 3/8	6 1/4	20 3/4	84	104	116	20
18XLZ25	9 5/8	6 1/4	20 3/4	109	135	150	26

[1] Without steel tray.
[2] With steel tray.

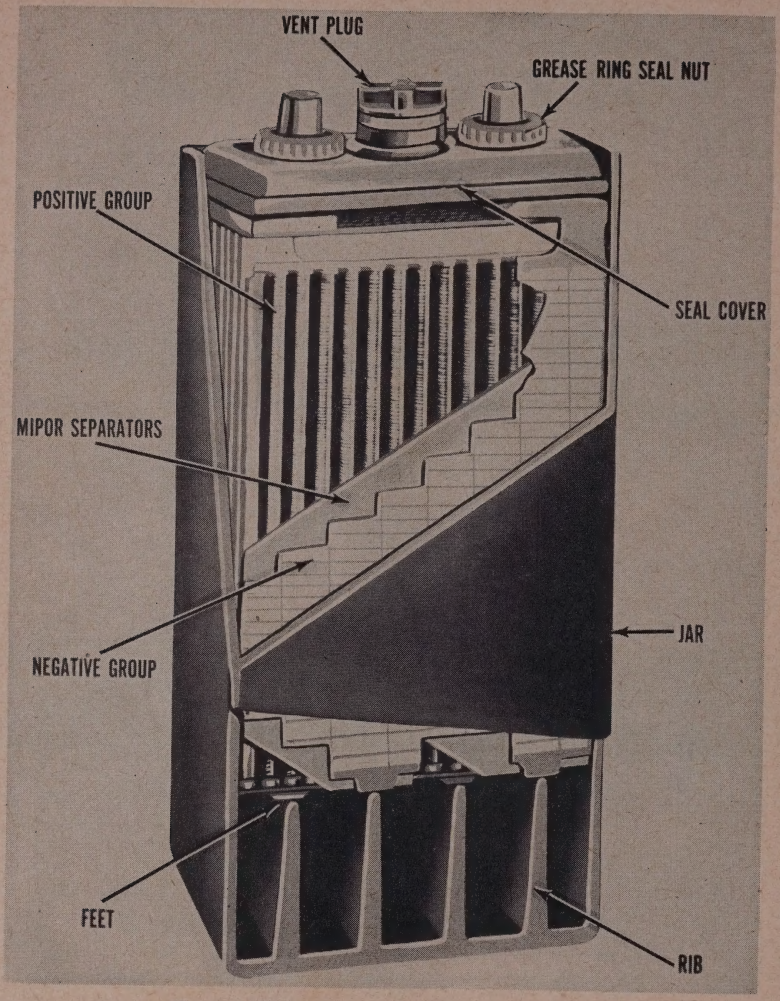
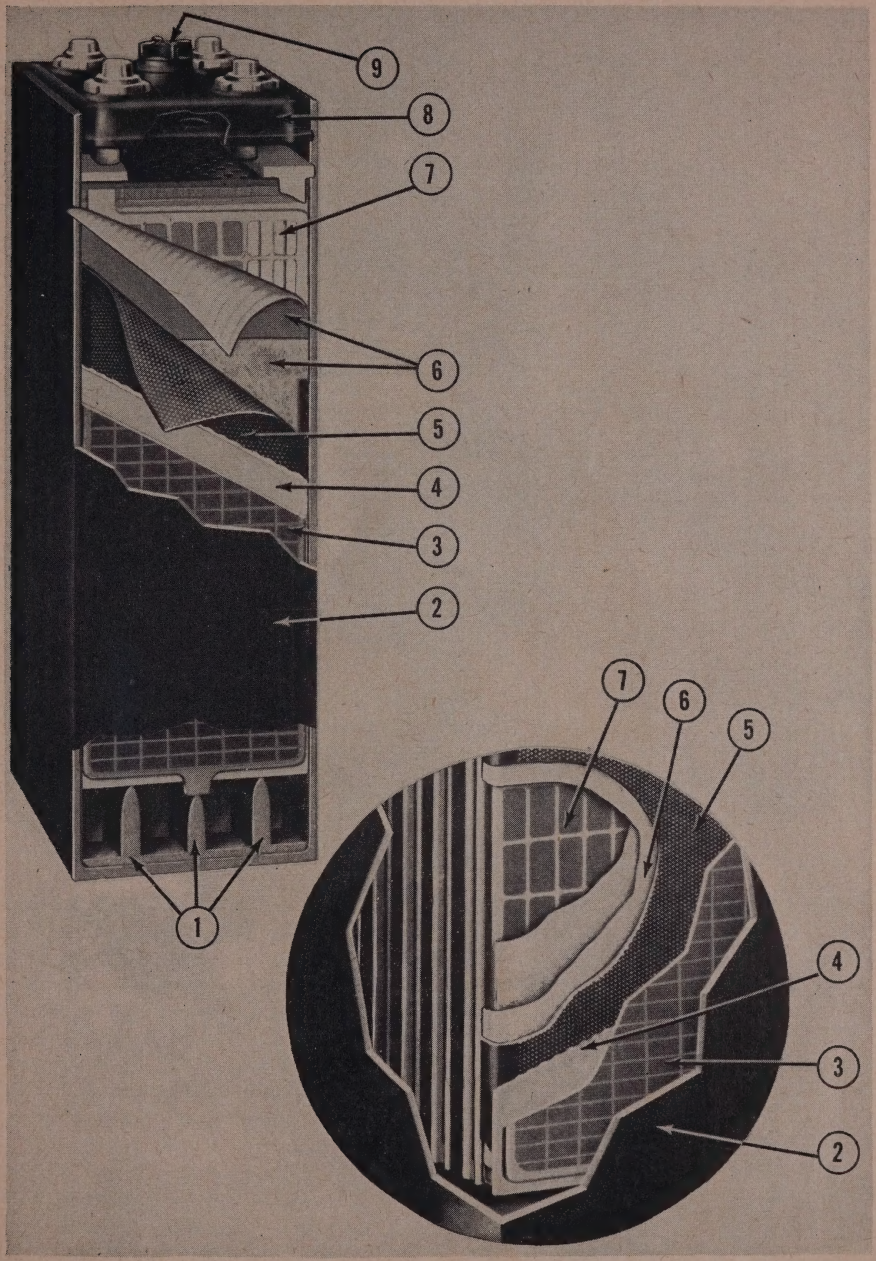


Figure 6. Cutaway view of an Exide bettery cell.

b. Groups. Each group from which the cell element is made consists of positive and negative plates that are permanently joined by welding the lugs on the top corner of each plate into slots on a lead plate strap. The lead plate strap contains a cylindrical terminal that forms the outside connecting post for the group. The negative group always contains one more plate than the positive group in order to provide a negative plate on both sides of all positive plates when the two groups are intermeshed (figs. 8 and 9). Separators, which are made of thin sheets of wood or porous rubber insulating material, are inserted between the plates to prevent them from touching and causing short circuits. The smooth sides of the separators are placed toward the negative plates; the grooved sides, toward the positive plates in order to provide spaces between separators and positive plate surfaces to permit gas to rise and to permit loosened active material to fall to the sediment space at the bottom of the assembled cell.



1	Ribs	4	Separator	7	Positive plate
2	Jar	5	Envelope	8	Cover
3	Negative plate	6	Slyver mats	9	Vent cap

Figure 7. Cutaway view of a C & D battery cell.

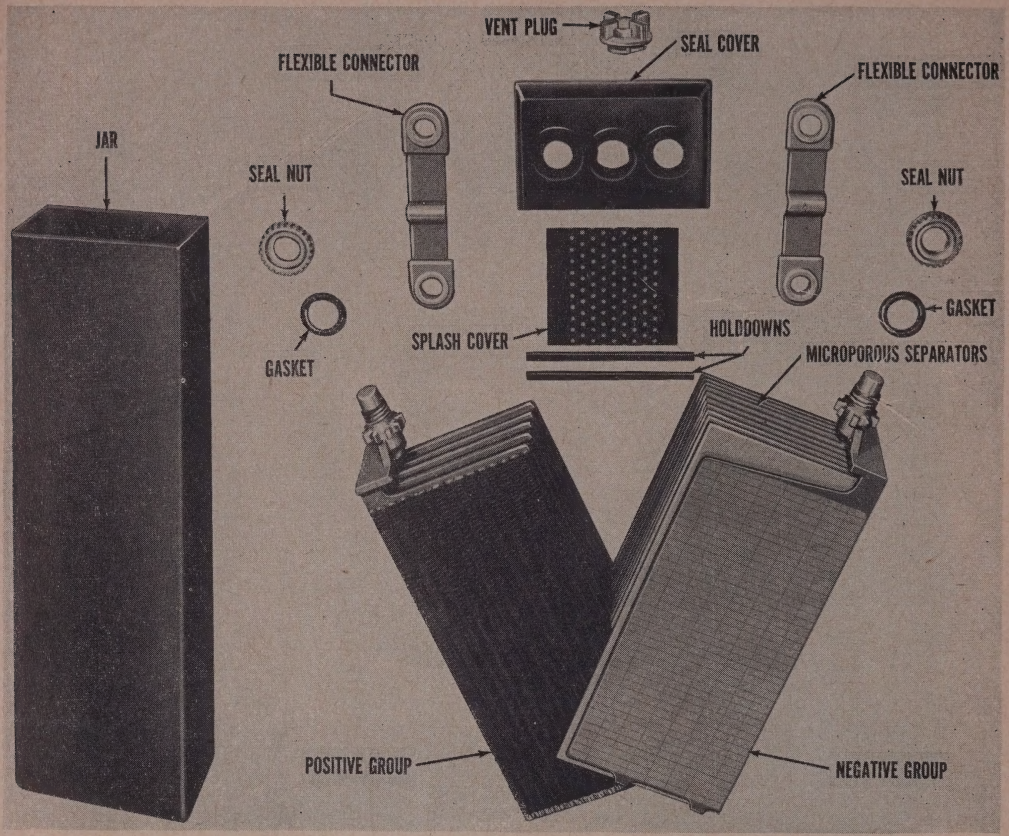


Figure 8. Components of an Exide cell.

c. Plates. Each plate used to construct the positive and negative plate groups that form a cell element is composed essentially of a grid, a framework of horizontal and vertical or diagonal conducting rods that support the active material. This active material, which is different for positive and negative plates, is acted upon by the electrolyte solution to release the energy that produces the current and voltage developed by the cell.

(1) *Positive plates.* Although plate construction and size (table IV) differ with the type of battery, the active material for all positive battery plates is originally lead oxide. This lead oxide is converted to lead peroxide by subjecting the plate to a forming charge before the plates are assembled to form a positive group of plates. The forming charge is an electrochemical process designed to accomplish the conversion of oxide to peroxide and to permanently secure the active material to the plate. Positive plates may be of a tubular or a pasted type.

(*a*) *Tubular type.* The grid of the tubular type positive plate used in Exide cell elements (fig. 10) consists of a heavy alloy crossbar cast with a series of vertical conducting rods. These conducting rods are the cores of the finely slotted, hollow, hard-rubber or plastic retaining tubes that house the active material (fig.

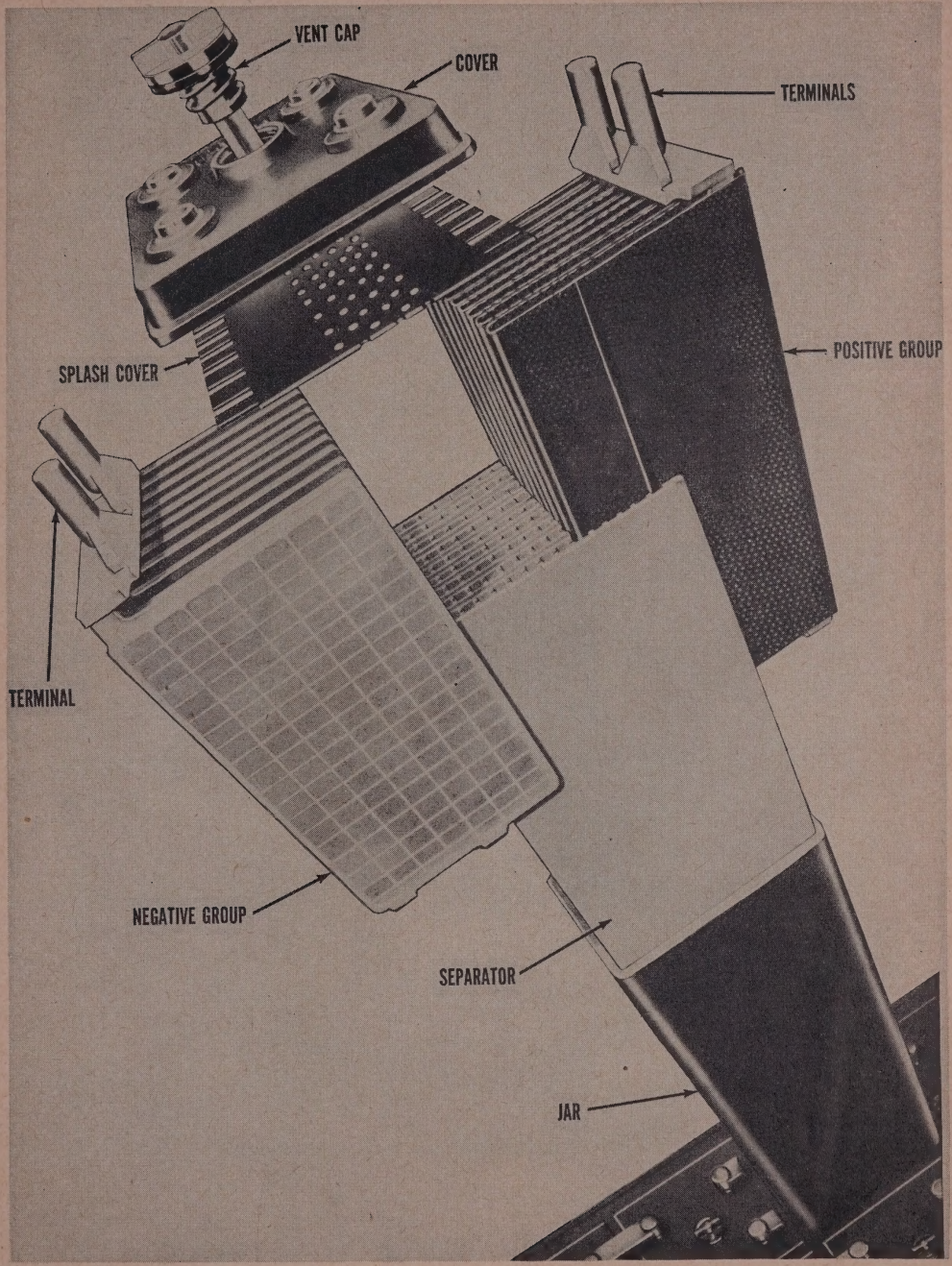


Figure 9. Components of a Gould cell.

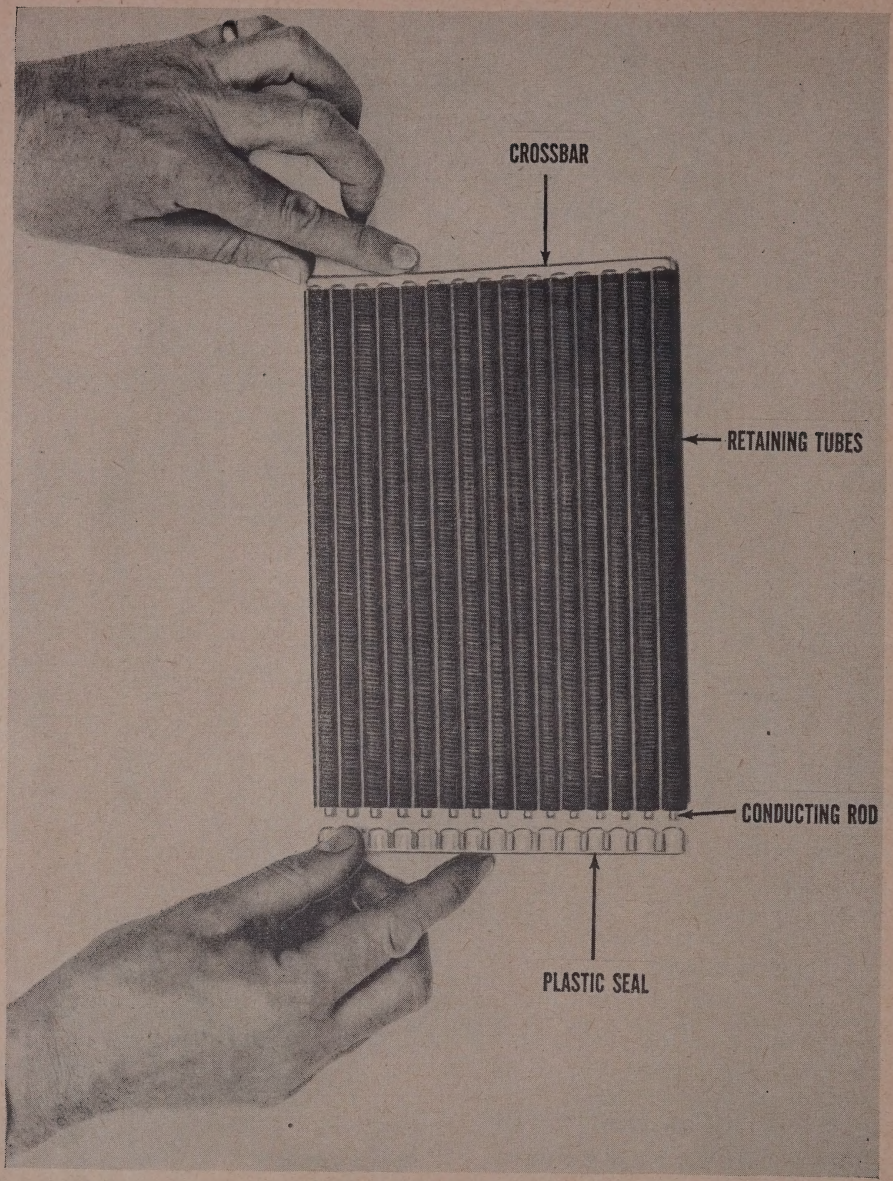


Figure 10. Tubular-type positive plate used in an Exide cell.

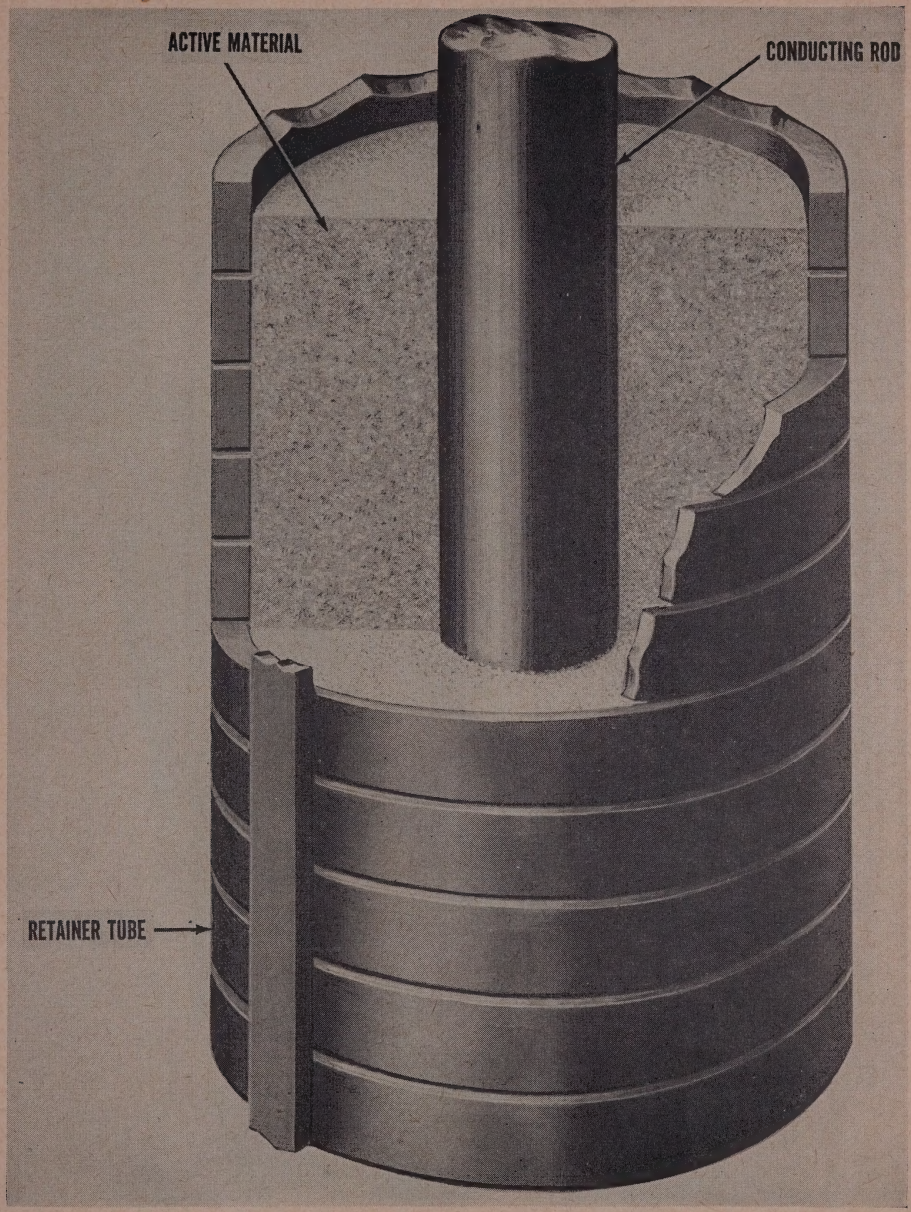


Figure 11. Cutaway view of an Exide positive plate tube.

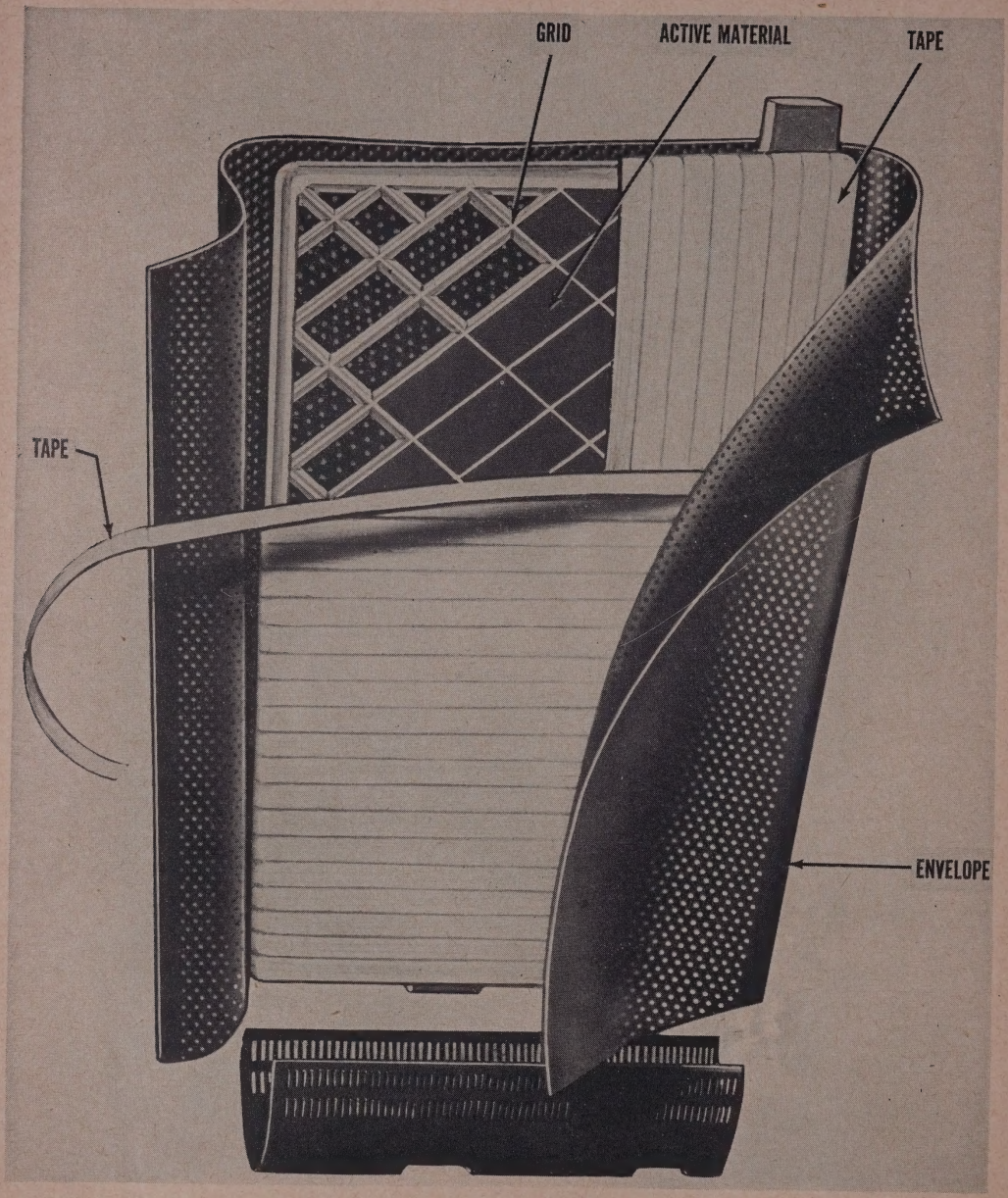


Figure 12. Positive plate of a Gould battery cell.

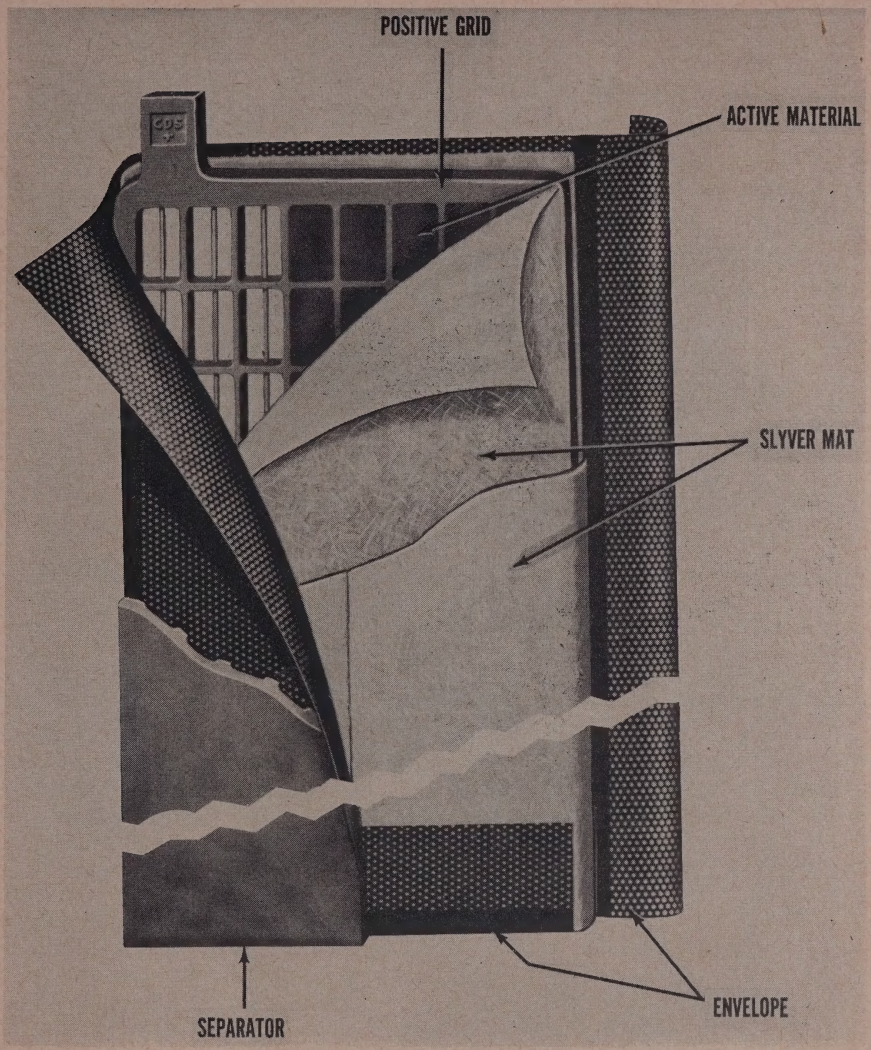


Figure 13. Positive plate of a C & D battery cell.

11). The tubes are sealed at the top by the crossbar of the grid and at the bottom by a plastic (polyethylene) tube sealer.

(*b*) *Pasted type.* The positive plates used in Gould and C & D batteries have the active material pasted between the horizontal and diagonal or vertical conducting rods of the grid. After the positive plates of a Gould cell (fig. 9) have been subjected to a forming charge, they are wrapped vertically and horizontally with a Fiberglas-type insulating tape (fig. 12) and enclosed in a plastic envelope. The positive plates of a C & D battery cell (fig. 7) are enclosed in several layers of Fiber-

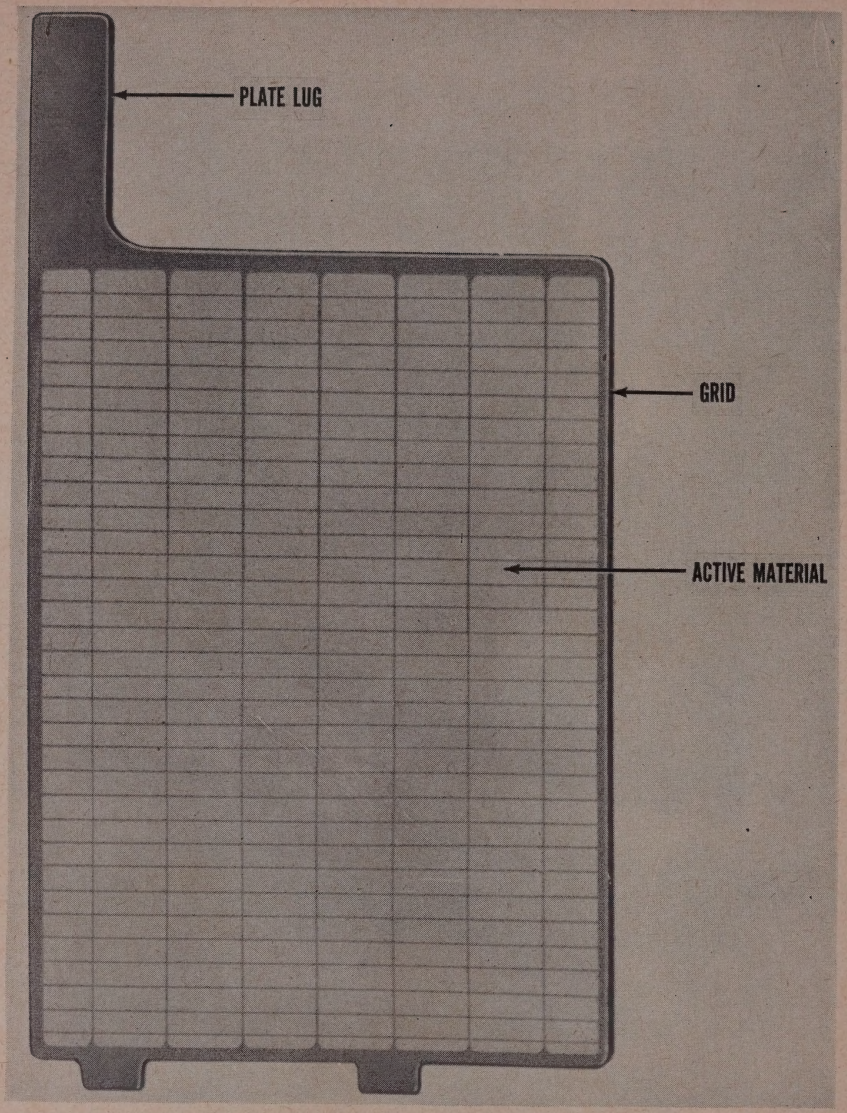


Figure 14. Typical negative plate for a lead-acid storage battery.

glas matting (Slyver) before being enclosed in a plastic envelope (fig. 13).

(2) *Negative plates.* Negative plates for the various types of batteries are similar in construction, and are of the pasted type (fig. 14). The active material is originally litharge (lead monoxide) or a combination of litharge and red-lead oxide. This material is converted to soft, spongy, gray lead by subjecting the plates to a forming charge before they are assembled to form a negative group of plates.

Table IV. Plate Specifications, Lead-Acid Batteries

Battery and model numbers	Plates					
	Height		Width		Thickness	
	Positive	Negative	Positive	Negative	Positive	Negative
	Inches	Inches	Inches	Inches	Inches	Inches
C & D:						
18CDS13	14 9/16	14 9/16	5 5/8	5 5/8	.250	.171
18CDS19	14 9/16	14 9/16	5 5/8	5 5/8	.250	.171
18CDS25	14 9/16	14 9/16	5 5/8	5 5/8	.250	.171
Exide:						
18TLM13	12 23/32	12 23/32	5 3/4	5 3/4	.183	.183
18TLM19	12 23/32	12 23/32	5 3/4	5 3/4	.183	.183
18TLM25	12 23/32	12 23/32	5 3/4	5 3/4	.183	.183
Gould:						
18XLZ13	13 3/8	13 3/8	5 5/8	5 5/8	.220	.160
18XLZ19	13 3/8	13 3/8	5 5/8	5 5/8	.220	.160
18XLZ25	13 3/8	13 3/8	5 5/8	5 5/8	.220	.160

Section III. PRINCIPLES OF OPERATION

5. Definitions

a. Ampere-Hour Capacity. The capacity of a battery is measured in ampere-hours, which is derived by multiplying the number of amperes of current that the battery will deliver by the number of hours the battery will deliver that number of amperes. The ampere-hour rating is calculated at a temperature of 77° F. with a specific gravity reading of 1.280. The ampere-hour capacity ratings of 18-cell lead-acid storage batteries are shown in table V. The utilization of these batteries by type of equipment is shown in table VI. Because of the standardization in battery compartment sizes, lead-acid as well as nickel-iron-alkaline batteries of approximately the same capacity may be used interchangeably.

b. Voltage. Voltage is a measure of electrical potential or electromotive force. One volt is that electromotive force required to deliver a current of 1 ampere through a resistance of 1 ohm. The nominal open-circuit voltage (voltage when not discharging) of a fully charged battery cell is approximately 2 volts. This is true regardless of the size of the cell. The voltage of an 18-cell lead-acid storage battery is stated, therefore, as 36 volts.

c. Normal Discharge Rate. The normal discharge rate of a battery is the number of hours (for 18-cell lead-acid batteries, 6 hours) that a battery will deliver its rated amperes per hour before battery potential (voltage) drops to 1.75 volts per cell.

Table V. Lead-Acid Storage Battery Capacities
(6-hour rate)

Battery and model numbers	Ampere-hour capacity	Amperes per hour
C & D:		
18CDS13	360	60
18CDS19	540	90
18CDS25	720	120
Exide:		
18TLM13	300	50
18TLM19	450	75
18TLM25	600	100
Gould:		
18XLZ13	330	55
18XLZ19	495	82.5
18XLZ25	660	110

Table VI. Utilization of Lead-Acid Storage Batteries

	Battery								
	C & D			Exide			Gould		
	18CDS13	18CDS19	18CDS25	18TLM13	18TLM19	18TLM25	18XLZ13	18XLZ19	18XLZ25
Truck, fork, electric, 2,000-lb., 130-in. lift.	X			X			X		
Truck, fork, electric, 4,000-lb., 144-in. lift.		X			X			X	
Truck, fork, electric, 6,000-lb., 168-in. lift.			X			X			X
Tractor, warehouse, electric, 2,000-lb. drawbar pull.		X			X			X	
Tractor, warehouse, electric, 4,000-lb. drawbar pull.			X			X			X
Crane, warehouse, electric, 6,000-lb. capacity.		X			X			X	

d. Discharge Limit. The discharge limit of a battery is the point below which complete sulphation is possible. This takes place when reactions in the cell cause sufficient accumulation of lead sulphate at both positive and negative plates to destroy the dissimilarity of the materials in the plates and to prohibit further electrochemical reaction. Habitual overdischarging and prolonged operation in an undercharged condition are the two major causes of sulphation. As sulphated plates are usually permanently damaged if allowed to remain in this condition too long, a servicing schedule should be followed to provide for adequate charging without subjecting the battery to an overcharge.

6. Theory of Operation

In theory, a storage battery operates because chemical energy can be converted into electrical energy and electrical energy, under certain circumstances, can be stored in chemicals. Electrical energy, introduced at the time of charging a battery, is stored as chemical energy within the cells of the battery. It is dispersed as electrical energy (direct current) when chemical reaction takes place at the time the battery is placed in operation.

7. Principle of Operation

In practice, the theory of conversion of chemical energy becomes the principle on which the storage battery operates. When the battery is placed on charge and electricity is passed from the charger (outside source) through the electrolyte-filled cells, certain chemical changes occur in the active materials contained in the battery cell. The new chemicals formed by the passage of electricity are unstable and, after the outside source of electricity is disconnected, the original chemical reactions reverse themselves to re-form the original chemicals and, at the same time, to release electrical energy.

8. Operating Cycle

The operation of a storage battery is cyclic, consisting of a discharging action that must be followed by a charging action. The service life of a battery is determined by the number of operating cycles per year. For maximum service life, it is recommended that a battery be restricted to 300 cycles annually. Charging and discharging actions are shown graphically in figure 15, and are discussed in *a* and *b* below.

a. Discharging Action. Discharge occurs when the terminals of a battery are connected to a closed circuit (the motor of electric-powered equipment). At this time, the sulphuric acid in the electrolyte, which consists of positively charged hydrogen particles (positive ions) and negatively charged sulphate particles (negative ions), starts to react with the active material in the positive and negative

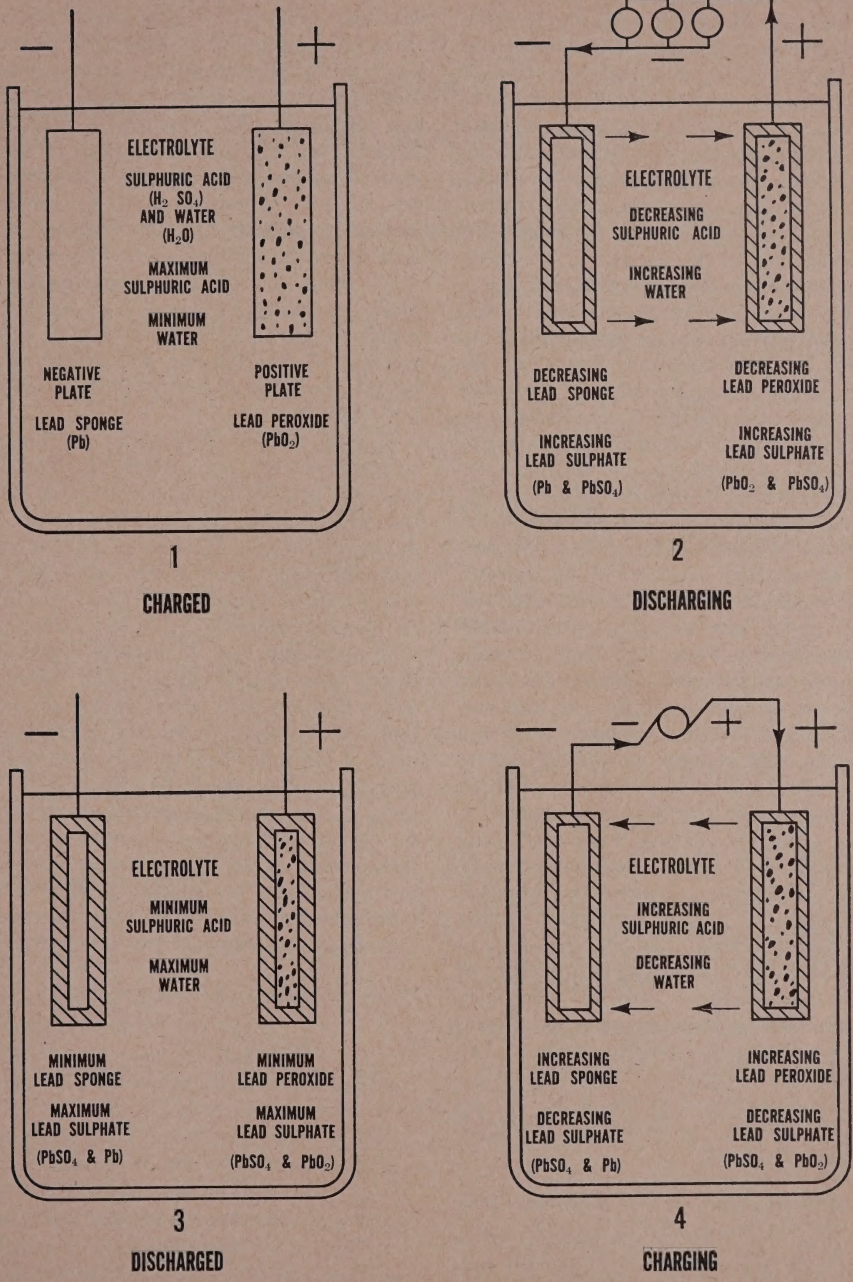


Figure 15. Chemical reactions in lead-acid batteries.

plates. The hydrogen combines with some of the oxygen of the lead peroxide at the positive plates to form water, and the sulphate combines with the lead liberated at the positive plates and with the spongy lead at the negative plates to form lead sulphate. At the same time, particles of negative electricity (electrons) are released at the negative plates and flow through the outside closed circuit to neutralize excessive positive particles of electricity at the positive plates. As discharging progresses the electrolyte becomes weaker due to the formation of water, and the active materials at both the positive and negative plates continue to be converted to lead sulphate until an effective electrochemical reaction is no longer possible. At this point, the battery is said to be approaching its discharge limit. The discharge limit will not normally be exceeded if the battery is charged at the end of a normal shift, at which time it will have expended approximately 75 percent of its capacity.

b. Charging Action. The charging action begins when the terminals of the battery are connected to an external source of direct current. The electrochemical reaction is reversed and returns the positive and negative plates to their original condition. Thus, the lead sulphate formed at the positive plates during discharge is re-converted to lead peroxide; the lead sulphate at the negative plates, to sponge lead; and the sulphuric acid content of the electrolyte solution is restored. Batteries should be charged whenever the specific gravity of the electrolyte falls below 1.200 for any one work shift; and should always be charged immediately when completely discharged. Particular attention should be given to proper ventilation during charging to make certain that cell temperatures do not rise above 110° F. A cell temperature of 130° F. is permissible, however, when dry charged batteries are being prepared for initial service. When specific gravity readings are taken (par. 21), proper correction must be made for temperatures in excess of 80° F. An adjustment must also be made for increased self-discharge (par. 32).

9. Effect of Temperature on the Operating Cycle

The normal operating characteristics of a storage battery are modified by unusually low or high atmospheric temperatures.

a. Low-Temperature Effect. Low temperatures reduce battery capacity because resistance and the viscosity of the electrolyte are increased. This tends to retard the flow of current through the electrolyte and to retard diffusion of the electrolyte through the pores of the cell plates. For example, a fully charged battery (specific gravity, 1.280) will deliver only 80 percent of its capacity at approximately 32° F.; only 65 percent at 0° F. Further, the electrolyte may freeze, the freezing temperature depending upon the specific gravity (table VII). Thus, to avoid freezing, to maintain adequate potential, and to enable the application of a proper charge, batteries should be kept fully charged in cold weather and should be heated during operation or storage at temperatures below —20° F.

b. High-Temperature Effect. Although high temperatures do not materially affect battery capacity, battery operation is affected. The electrolyte is more active and diffuses more readily during discharge. This allows more active plate material to take part in the electrochemical reaction and, as a result, full charge specific gravity may be reduced to 1.200 to 1.225 by dilution with distilled water. If distilled water for dilution of electrolyte is not available, rain water or water that has been tested for low mineral content may be used. When the electrolyte is diluted, a tag indicating the adjusted full charge specific gravity should be attached to the battery. A comparison of specific gravity readings for operation in temperate and tropical climates is shown in table VII. Special care must be taken to adjust the specific gravity to normal before batteries are shipped to areas where they may be exposed to freezing temperatures.

Table VII. Effect of Temperature on Battery Capacity

State of charge	Standard specific gravity for temperate operation	Freezing point (Fahrenheit)	Reduced specific gravity for tropical operation
Percent		Degrees	
100	1.280	—95	1.200
75	1.250	—62	1.180
50	1.220	—31	1.135
25	1.160	+1	1.090
10	1.130	+10	1.045

CHAPTER 2

USE AND MAINTENANCE

Section I. PREPARATION FOR USE

10. Establishing Requirements

The number of batteries required for service depends primarily upon the number of 8-hour shifts in effect. Normally, for operation on a single-shift basis, the number of batteries required will be the same as the number of items of equipment, and the batteries need not be removed from the trucks for charging. For operation on a 2- or 3-shift basis, the number of batteries required will be twice the number of items of equipment, and it will be necessary to exchange discharged batteries for charged batteries at the end of each work shift. For operation on a multiple-shift basis, 16 hours is the estimated maximum service time for any one battery within a 24-hour day, and 24 hours the maximum service time within a 48-hour period. For 3 shifts, therefore, 3 batteries will be required per item of equipment.

Note. The estimates above are based on the average 7 to 8 hours required to recharge a completely discharged lead-acid battery.

11. Uncrating and Unpacking

a. Inspect each battery crate on delivery for damage. Report damage to the superior officer in charge.

b. Make certain that crate is right side up (with skid mounts resting on floor).

c. Use a forklift truck or crane of at least 3,000-pound capacity to remove the crated battery (fig. 16) from the truck or railroad car. If a crane is employed, be sure that sling placed around crate is secured against bottom of skid and not around skid mounts.

d. Move crated battery from vehicle on which it was shipped to uncrating area.

e. Lower crated battery to floor and remove forklift fingers or crane sling.

f. Cut wire band around crate with wire cutters.

g. With screwdriver, pry off staple locking wire band to top of box.

h. Using a claw hammer, remove nails from the boards that secure both sides of the crate to the skid mount.

i. When crate is freed from skid mounts, lift crate off battery.

j. Remove box containing battery hydrometer.

k. Remove waterproof paper that covers the battery.

l. Inspect battery for damage and report any irregularities to the superior officer in charge.

m. Remove plastic protector that covers the charging connector.

n. Remove sealing paper that is over filler vents.

o. Attach 2 chains from a spreader bar to both ends of the battery and lift battery from skid mounts.

Caution: Enough tension must be maintained by the spreader bar on the chains at all times, so that they do not touch the terminals of the battery and cause a short circuit.

12. Preparing Batteries for Use

a. Charged and Wet Batteries. Charged and wet batteries are shipped with cells filled with electrolyte and all plates fully charged. To prepare these batteries for use, proceed as follows:

(1) Examine battery to see if electrolyte has been accidentally spilled. If so, wipe off spilled electrolyte with a rag that has been dipped in ammonia or soda solution. Rinse with clear water; dry battery thoroughly.

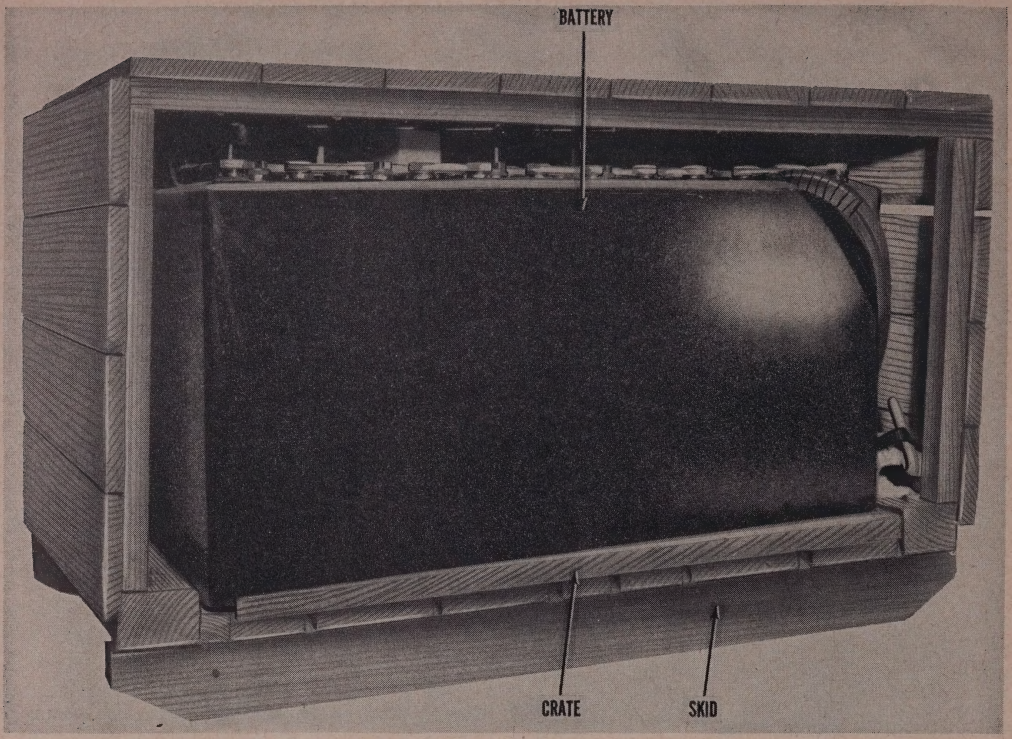


Figure 16. Lead-acid battery partially uncrated.

(2) Remove vent plugs and check level of electrolyte in each cell. Take specific gravity reading of pilot cell (par. 21) and add electrolyte of same specific gravity to bring level above plate tops. Install vent plugs and check to see if all vent holes are open.

(3) Check each row of cells to see that positive terminal of one cell is connected to negative terminal of the next. See that all cell connectors are in place and secure.

(4) Administer a freshening charge (par. 18*d*).

b. Charged and Dry Batteries. Charged and dry batteries are shipped with dry, charged plates and without electrolyte in the cells. The vents of each cell are sealed and must remain so until the battery is ready for processing. A charged and dry battery will give approximately one-half to two-thirds rated capacity when placed in service. Subsequent discharging will be normal. Prepare these batteries for service as follows:

(1) Remove vent plugs and destroy the sealing device over the filler holes.

(2) Fill each cell to the proper level with electrolyte having a specific gravity 1.255 to 1.270 unless otherwise specified by the manufacturer. Install vent plugs and allow battery to stand for 10 to 15 hours.

(3) Remove vent plugs and check level of electrolyte in each cell. Add electrolyte of same specific gravity to bring level above plate tops, if necessary. Install vent plugs.

(4) Wipe off any spilled electrolyte with soda solution, rinse with clear water, and dry thoroughly.

(5) Administer a freshening charge (par. 18*d*) for approximately 12 hours or until four consecutive hourly specific gravity readings indicate no rise in specific gravity or voltage.

c. Uncharged and Dry Batteries. Uncharged and dry batteries are shipped with uncharged dry plates and without electrolyte. The vents of each cell are sealed and must remain so until the battery is prepared for charging. An uncharged and dry battery will deliver approximately 75 percent of rated capacity when placed in service. Subsequent charges will bring battery up to full capacity. Prepare these batteries for service as follows:

(1) Remove the vent plugs and destroy the sealing compound over the filler holes.

(2) Fill each cell to the proper level with electrolyte having a specific gravity of 1.275 to 1.280. Mix electrolyte by charging at finish rate if necessary. Install vent plugs and allow battery to stand for 12 to 16 hours.

Note. Exide batteries use 1.250 electrolyte. At end of charge specific gravity will be 1.275.

(3) Remove vent plugs and check level of electrolyte. Bring to proper level, if necessary, by using electrolyte of same specific gravity.

(4) Place battery on charge at finish rate (par. 18*d*) for 96 hours.

(5) During charge, take individual cell voltage, specific gravity, and temperature readings every 4 hours. Battery will be charged when voltage and specific gravity no longer show increase. If temperature approaches 110° F., stop charge and allow battery to cool. Then continue charge for full 96-hour period.

(6) Upon completion of charge, take specific gravity reading. If it varies more than .005 point for normal full-charge reading, a high or low gravity adjustment (par. 22*a*) must be made.

Section II. CHARGING

13. General

Charging is the process of passing direct current through the cells of a battery in a direction opposite to that of discharging for as long as needed to replace the number of ampere-hours taken from the battery during service plus a 10 percent excess.

14. Charging Equipment

Approved charging equipment provides completely automatic control of charging. Charging rates, length of charge, and discontinuance are accomplished by means of voltage relays and timers or ampere-hour meters built into or used in conjunction with charging equipment. Only direct current can be used for charging. If alternating current is available, it must be converted to direct current by means of approved motor generators or rectifiers.

a. Motor Generator. The standard motor-generator charger (Federal Specification W–C–256a) is the combination or conversion type that can be used with either 18-cell lead-acid or 30-cell nickel-iron-alkaline storage batteries. It operates on a 220-volt, 60-cycle, 3-phase power line and may be equipped with single or multiple charging circuits.

b. Rectifier. The standard rectifier is the Charger, storage battery, combination-type, 18-cell lead-acid or 30-cell nickel-iron-alkaline storage battery, 220-volt, 60-cycle, 3-phase, single-circuit, metallic rectifier charger (Quartermaster Stock Number 17–C–8785–75).

15. General Charging Principles

The charging of a lead-acid battery is characterized by a high starting rate that is usually 3 to 5 times that of the finishing rate. This rate automatically tapers to the finishing rate as the battery approaches full charge. The tapering of the charging rate may be gradual or it may be characterized by a sharp reduction at a specified voltage. The manner in which the tapering takes place is the difference between the two accepted charging methods (par. 16).

a. Establishing Polarity. Special care must be taken to see that proper polarity is maintained when the battery is attached to the charger. The positive terminal of the battery connector must be connected to the positive terminal of the charger; and the negative terminal of the battery connector to the negative terminal of the charger. Reversing the polarity will result in permanent damage to the battery.

b. Determining Rate. A battery may be charged at any rate in amperes that will not produce excessive gassing of the electrolyte or a cell temperature of more than 110°F. As a general rule, the charging rate in amperes should never exceed the value of the ampere-hours discharged from the battery measured from the full state of charge. It should be noted that the maximum allowable charging rate depends entirely upon the actual state of discharge and the number of ampere-hours out of the battery and not upon the estimated state of discharge or the capacity of the battery.

c. Controlling Gassing. Gassing is a natural phenomenon which takes place when a battery on charge can no longer accept all the current being applied to it. Gassing is evidenced by bubbling of the electrolyte. The gases liberated are oxygen, evolved at the positive plates during charge; and hydrogen, evolved at the negative plates. The point at which gassing begins is determined by voltage, but the amount of gas depends upon the portion of the current (charging amperage) that is not absorbed by the battery. Normally, gassing will begin when the voltage at the terminals of the battery has reached 2.30 volts per cell. At 2.40 volts per cell, gassing will be normal and at 2.50 volts per cell, it will be rapid. The amperage at which gassing becomes excessive depends primarily upon the state of charge and cell temperature. As the battery approaches full charge, therefore, it is necessary to reduce the charging rate to a point at which excessive gassing is prevented. This safe rate is known as the finishing rate, and it is normally 5 amperes per 100 ampere-hours of battery rating. When approved charging equipment is used, the tapering of the charging current to the finishing rate is achieved automatically. Finishing rates are normally prescribed by the battery manufacturer. A compilation of these approved rates appears as table VIII.

Note. Never charge above the finishing rate when the cell terminal charging voltage is 2.37 or higher.

d. Determining Voltage. The charging voltage depends upon the charging method used (par. 16). Generally, the charging of a battery may be accomplished at any voltage high enough to permit the charge to be completed in the desired time. However, the standard voltage adopted for the charging of lead-acid batteries during a 7-hour period by the modified constant voltage method is 2.63 volts per cell or 47.34 volts for an 18-cell battery. The standard voltage adopted for use with the two-rate method is 2.70 volts per cell or higher.

e. Limiting Time. Certain time elements have been calculated for the various reactions that occur during a battery charge. When the battery is first put on charge there is a sharp rise in terminal voltage of the cells. This is caused by the sudden concentration of electrolyte as sulphuric acid is liberated in the pores of both positive and negative plates. As the charge progresses, the diffusion process checks the rise in battery voltage, and, after about 2 to 2½ hours, this diffusion results in an increase of specific gravity. Gassing begins at 4 to 4½ hours, at which time the charger should have reduced charging current to the finishing rate. At the end of 7 hours, the active material is recharged, specific gravity and voltage reach their maximum, and the battery is charged.

Table VIII. Finishing Rates of Lead-Acid Batteries

Battery and model numbers	Finishing rate
	Amperes
C & D:	
18CDS13	15
18CDS19	25
18CDS25	35
Exide:	
18TLM13	15
18TLM19	23
18TLM25	30
Gould:	
18XLZ13	16
18XLZ19	24
18XLZ25	33

16. Charging Methods

a. General. Charging may be accomplished by a modified constant-voltage method and a two-rate method. Under the two-rate method it is possible to adjust the charger for the proper finish rate when cell voltage reaches 2.37 volts per cell. Under the modified constant-voltage method it is impossible to make a finishing adjustment without affecting the starting rate. Rectifiers may be used in the two-rate method but are not normally used in the modified constant-voltage method.

b. Modified Constant-Voltage Method. The modified constant-voltage (potential) method, in which the tapering of the charging rate is accomplished gradually, is normally used in conjunction with motor-generator charging equipment when a bus voltage of 2.63 volts per cell is available. This method provides inherently a starting rate as high as needed to permit the charge to be completed in the desired time and that automatically tapers to the finishing rate recommended by the battery manufacturer (table VIII). In this method, the tapering of the charge rate is usually controlled by a voltage relay and timer, although an ampere-hour meter may be used successfully.

c. Two-Rate Method. The two-rate method, in which the tapering of the charging rate is characterized by a sudden drop, is normally used in conjunction with rectifier chargers or when a dc bus voltage of 2.70 volts or higher is available. This method provides a high rate during the first and greater portion of the charge, and a low (finish) rate for the remainder of the charge. The change from the high rate to the finish rate occurs at the gassing point, which is when the battery is approximately 80 percent charged or when individual cell voltage reaches 2.37 volts per cell.

17. Charge-Control Equipment

Charging rate and termination of charging are controlled automatically by the use of ampere-hour meters or voltage relays and timers. Regardless of the type used, control equipment is interconnected to the charger by contactors or electromagnetic switches.

a. Ampere-Hour Meter.

(1) *Types.* Ampere-hour meters are available in two types, those mounted on the control panel of the charging equipment and those mounted on the truck or tractor. These meters are equipped with an adjustable resistor to regulate the percentage of overcharge given during each charge. The normal setting for lead-acid batteries is 10 to 15 percent overcharge. Thus, the ampere-hour meter allows the charge to be continued until the ampere-hours discharged from the battery have been replaced together with the required 10 percent overcharge.

(2) *Use.* Ampere-hour meters mounted on the control panel of charging equipment are control devices. They must be set before each charge to correspond with the state of discharge of the battery in order that the number of ampere-hours expended by the battery can be replaced. To set an ampere-hour meter, it is necessary to take a specific reading of a pilot cell (par. 21*a*) and refer to an ampere-hour meter chart (table IX) to obtain the correct meter setting. Once the ampere-hour meter has been set, no further adjustment to the meter should be made, as overcharging might result. After the ampere-hour meter automatically cuts off the charging equipment, specific gravity readings should be taken to verify completion of the charging operation. Truck mounted meters, which are connected into the positive line of the power circuit of the truck, indicate both charge and extent of discharge and do not have to be reset when the battery is placed on charge in the truck.

TABLE IX

AMPERE-HOUR METER CHARGING CHART

SPECIFIC GRAVITY AT START OF CHARGE (77° F.)	AMPERE-HOUR METER SETTINGS (Batteries fully charged to 1.280 specific gravity at last equalizing charge)									AMPERE-HOUR METER SETTINGS (Batteries fully charged to 1.260 specific gravity at last equalizing charge)									AMPERE-HOUR METER SETTINGS (Batteries fully charged to 1.250 specific gravity at last equalizing charge)								
	13 PLATES PER CELL BATTERIES			19 PLATES PER CELL BATTERIES			25 PLATES PER CELL BATTERIES			13 PLATES PER CELL BATTERIES			19 PLATES PER CELL BATTERIES			25 PLATES PER CELL BATTERIES			13 PLATES PER CELL BATTERIES			19 PLATES PER CELL BATTERIES			25 PLATES PER CELL BATTERIES		
	E	G	C&D	E	G	C&D	E	G	C&D	E	G	C&D	E	G	C&D	E	G	C&D	E	G	C&D	E	G	C&D	E	G	C&D
1.280												AMPERE-HOUR METER SETTINGS																
1.270	20	22	24	30	33	36	40	44	48																		
1.260	40	44	48	60	66	72	80	88	96																		
1.250	60	66	72	90	99	108	120	132	144	20	22	24	30	33	36	40	44	48									
1.240	80	88	96	120	132	144	160	176	192	40	44	48	60	66	72	80	88	96	20	22	24	30	33	36	40	44	48
1.230	100	110	120	150	165	180	200	220	240	60	66	72	90	99	108	120	132	144	40	44	48	60	66	72	80	88	96
1.220	120	132	144	180	198	216	240	264	288	80	88	96	120	132	144	160	176	192	60	66	72	90	99	108	120	132	144
1.210	140	154	168	210	231	252	280	308	336	100	110	120	150	165	180	200	220	240	80	88	96	120	132	144	160	176	192
1.200	160	176	192	240	264	288	320	352	384	120	132	144	180	198	216	240	264	288	100	110	120	150	165	180	200	220	240
1.190	180	198	216	270	297	324	360	396	432	140	154	168	210	231	252	280	308	336	120	132	144	180	198	216	240	264	288
1.180	200	220	240	300	330	360	400	440	480	160	176	192	240	264	288	320	352	384	140	154	168	210	231	252	280	308	336
1.170	220	242	264	330	363	396	440	484	528	180	198	216	270	297	324	360	396	432	160	176	192	240	264	288	320	352	384
1.160	240	264	288	360	396	432	480	528	576	200	220	240	300	330	360	400	440	480	180	198	216	270	297	324	360	396	432
1.150	260	286	312	390	429	468	520	572	624	220	242	264	330	363	396	440	484	528	200	220	240	300	330	360	400	440	480
1.140	280	308	336	420	462	504	560	616	672	240	264	288	360	396	432	480	528	576	220	242	264	330	363	396	440	484	528
1.130	300	330	360	450	495	540	600	660	720	260	286	312	390	429	468	520	572	624	240	264	288	360	396	432	480	528	576

E – Batteries (Exide) manufactured by Electric Storage Battery Company

G – Batteries (Gould) manufactured by Gould-National Batteries, Inc.

C&D – Batteries (C&D) manufactured by C&D Batteries, Inc.

(3) *Limitation.* While the ampere-hour meter has been successfully employed in the charging of lead-acid batteries by the modified constant-voltage and two-rate method and with the use of motor-generator or rectifier-type charging equipment, the objective of completely automatic charging has placed certain restrictions on it use. The use of the adjustable resistor, for example, overcharges the battery on a percentage basis that fails to take into account the total time between charges. Also, the ampere-hour meter must be modified for use with the two-rate method to provide additional contacts for adding resistance to the charging circuit to lower the charging rate from the starting rate to the finishing rate when the battery has been 80 to 85 percent charged. It has become common practice, therefore, to employ a voltage relay and timer, which eliminates the necessity of making any manual adjustment in accordance with prior discharge, as determined by the operator, for automatic control of battery charging.

Note. Table IX is divided into three sections, based on different fully charged specific gravity readings. If maximum specific gravity reading, as determined by last equalizing charge specific gravity, was 1.280, use the left section; if reading was 1.260, use the middle section; if reading was 1.250, use the right section. Do not use the section for 1.280 specific gravity reading on batteries with lower specific gravity. If maximum performance is required, it will be necessary to charge batteries in accordance with the proper section of the table and then make adjustments until four consecutive hourly specific gravity readings show no specific gravity increase.

b. Voltage Relay and Timer. The voltage relay and timer is actually a temperature-compensated relay and time clock. It is the generally accepted device for charging lead-acid batteries by the modified constant-voltage method when motor-generator charging equipment is used, and for charging lead-acid batteries by the two-rate method when rectifier-type charging equipment is used.

(1) *With modified constant voltage charging method.* When the modified constant voltage method is used, connect the battery to the charger, set the charger for the desired starting rate, and set the timer at 2½ to 3½ hours. The charger will charge the battery at the starting rate until cell voltage reaches 2.37 volts per cell at 77°F., at which time the voltage relay starts a timing device that automatically cuts off the charging at the preset time. It will then be necessary to take the hydrometer reading of a pilot cell and, if the battery is not fully charged, to continue charging at the finishing rate for as long as required.

(2) *With two-rate charging method.* When the two-rate method is used, connect the battery to the charger and set the timer on the charger control panel to approximately 3 hours. As the charging operation begins, observe the charging rate shown on the ammeter on the charger control panel. If the rate does not coincide with the prescribed starting rate for the battery being charged (table X), shut the charger off and open the hinged door of the battery charger and move the adjusting bus bar to the right or left to a point at which the starting rate will be within the specified range. Close the hinged door and start the charger. The charger will charge the battery at the starting rate until cell voltage reaches 2.37 volts per cell at 77°F. At this point, the voltage relay will not only activate the timer but will also reduce the charging rate from the high to the low finishing rate. On certain types of rectifier chargers a red pilot light, which operates during the high-charge period, will shut off and a green pilot light, denoting the low-rate charging period, will be lighted. At this time, it will be necessary to shut off the charger and recheck the charging rate. If it does not correspond to the finishing rate shown in table VIII, the adjusting bus bar

must be moved to the required setting and the charger restarted and allowed to run until the timer automatically terminates the charge. Once the rectifier-type charger has been set, it need not be changed except to charge batteries of a different type capacity.

Table X. Two-Rate Charging Starting Rates for Lead-Acid Batteries

Ampere-hour capacity	Starting rate
	Amperes
200–250	50–60
250–300	60–70
300–350	80–90
350–400	90–100
400–450	100–115
450–500	115–125
500–550	125–140
550–600	140–160

18. Types of Charge

a. Routine Charge. A routine charge is a charge administered at prescribed starting and finishing rates at the end of a working day or a normal work shift. The time required for charging depends upon the state of discharge or number of ampere-hours out of the battery. As a general rule, a battery should be charged when the specific gravity falls to 1.200. Charging before this limit is reached is a matter of common sense and knowledge of the work to be performed. Normally, a battery should be allowed to expend at least 50 percent of its capacity before a charge is administered.

b. Equalizing Charge.

(1) *General.* An equalizing charge is a charge administered after a routine charge has been completed. It consists of following the routine charge with a 3- or 4-hour charge at a rate no higher than the finishing rate. In normal service, a battery should receive an equalizing charge twice a month. If the battery requires less than one charge a week, every fifth or sixth charge should be an equalizing charge. When an equalizing charge is administered to a battery that has been out of service for a long period, the charge should be continued until all cells are gassing freely and until three consecutive hourly specific gravity readings show no further increase.

(2) *Using modified constant voltage method.* When an equalizing charge is given by the modified constant voltage method, the charge should begin when the ampere-hour meter shows by a zero reading that the normal charge has been completed. At this point it will be necessary to set the ampere-hour meter for the desired excess ampere-hour input, and to continue charging at the finishing rate for 4 hours while taking hourly specific gravity readings of all cells. If it is found that any one cell is not charged to the same extent as the rest, an inspection of the battery will be necessary. To complete an equalizing charge, an additional charge equal to 20 percent of the ampere-hours indicated on the charging chart (table IX) is required.

(3) *Using two-rate method.* When an equalizing charge is given by the two-rate method, the charge should begin at the end of the normal charge. At this point, it will be necessary to set the timer for 4 additional hours of charge at the finishing rate and to take four hourly specific gravity readings of all cells.

c. Booster Charge. A booster charge is administered only in extreme emergency when the ampere-hour capacity of the battery may be insufficient for the day's work or when it is not possible or practical to administer a routine charge. A booster charge is a charge administered at a high rate for a short period that is limited to prevent overcharging. When used, a booster charge should be administered between the morning and afternoon shift.

d. Freshening Charge. A freshening charge is normally administered when batteries are prepared for initial use and after they have been in storage for 30 or more days. A freshen-

ing charge consists of charging the battery at the finishing rate until the specific gravity of the electrolyte ceases to rise. The specific gravity and the voltage readings should be taken on all cells.

19. Charging Precautions

a. Make certain that vent plugs are kept seated while the battery is being charged except when taking specific gravity readings or cell temperatures, or when removing excess electrolyte.

b. Make certain that cell temperature does not exceed 110° F. during charging. If excessive temperatures are noted, stop charging immediately and allow battery to cool. Make certain that charger and charging areas are well ventilated.

c. Do not use the same hydrometer syringes, test forks, or other devices used on nickel-iron-alkaline batteries.

d. Observe gassing carefully, particularly near the end of charge. Excessively violent gassing indicates that the battery is becoming overcharged.

e. Never allow metal objects to come in contact with conducting elements of the battery.

f. Take precautions to prevent electrolyte from coming in contact with the skin or clothing. If electrolyte is spilled on the hands, do not touch the eyes or mouth and wash hands immediately in a soda solution. If electrolyte comes in contact with the eyes, wash eyes immediately in boric acid solution.

g. Never smoke or light matches in the charging area.

Section III. ROUTINE SERVICING

20. Adding Water

a. General. The addition of distilled water to battery cells is necessary to maintain the proper concentration and level of electrolyte in the cells. To determine if water is required, check the water level weekly. If a battery is scheduled for charging, add water immediately before charging. Never add water during or immediately after charging.

b. Procedure.

(1) Inspect level of each cell. If one cell has a consistently lower level than others, examine the cell for leakage.

(2) Use a 1-gallon gravity battery filler (Federal Specification W–B–177), and fill each cell to its approved level. The approved level for Exide batteries with TLM cells is ¼ inch below the bottom ring of the filling tube (fig. 17); for Gould batteries with XLZ cells, 2⅝ inches above plate tops or 1½ inches above the baffle; for C & D batteries with CDS cells, 1/12 inch above plate tops. C & D batteries are equipped with correct high-level indicators located about ¼ inch below the bottom of the vent wall.

21. Measuring Specific Gravity

The specific gravity of the electrolyte in a lead-acid storage battery indicates the state of charge of the battery. To obtain the state of charge, a specific gravity reading must be made and this reading corrected for temperature deviations from a standard temperature (80° F.). From the corrected specific gravity, the state of charge of the battery is obtained by means of table XI.

a. Taking Reading. Specific gravity readings are normally taken with a hydrometer-syringe assembly consisting essentially of a calibrated glass float (hydrometer) that is free to move vertically inside the glass cylinder of a syringe. The hydrometer is designed to float at a definite level in all liquids of like density but at different levels in all liquids of unlike densities. To take a specific gravity reading of the electrolyte in a battery, proceed as follows:

(1) Choose a pilot cell, remove the cell vent plug, and insert nozzle of the hydrometer-syringe assembly with the electrolyte in the cell.

Note. After the same pilot cell has been used for approximately 50 samplings, select a different cell as the pilot cell.

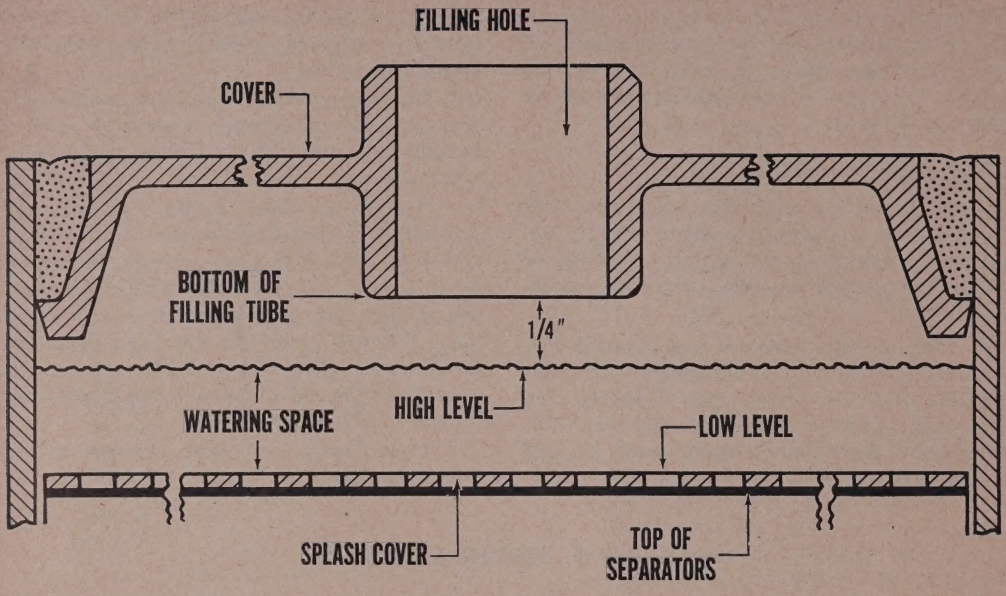


Figure 17. Diagram showing electrolyte level in Exide battery cell.

(2) Squeeze the syringe bulb and then slowly release it, drawing into the cylinder of the syringe just enough electrolyte to float the hydrometer freely. If hydrometer touches top of syringe, too much electrolyte has been drawn up; if hydrometer touches bottom of cylinder, too little electrolyte has been drawn up.

(3) Read hydrometer with eye at same level as electrolyte (fig. 18). The reading of the hydrometer at the surface of the liquid is the uncorrected specific gravity of the electrolyte.

(4) Return all electrolyte to cell.

(5) Use a Fahrenheit thermometer, and take the temperature of the electrolyte in the pilot cell.

(6) Replace cell vent plug.

b. Adjusting Reading and Determining State of Charge.

(1) Note the specific gravity and temperature readings as observed in (3)–(5) of *a* above. Add .003 to the observed specific gravity reading for each 10° integral of electrolyte temperature above 80° F.; subtract .003 from the specific gravity reading for each 10° integral of temperature below 80° F.

(2) Use table XI and determine the state of charge indicated by the corrected specific gravity.

Table XI. State of Charge and Specific Gravity Readings

Specific gravity	State of charge
	Percent
1.280	100
1.270	92
1.260	83
1.250	75
1.240	68
1.230	59
1.220	50
1.210	43
1.200	34
1.190	25
1.180	18
1.170	10
1.160 and below	0

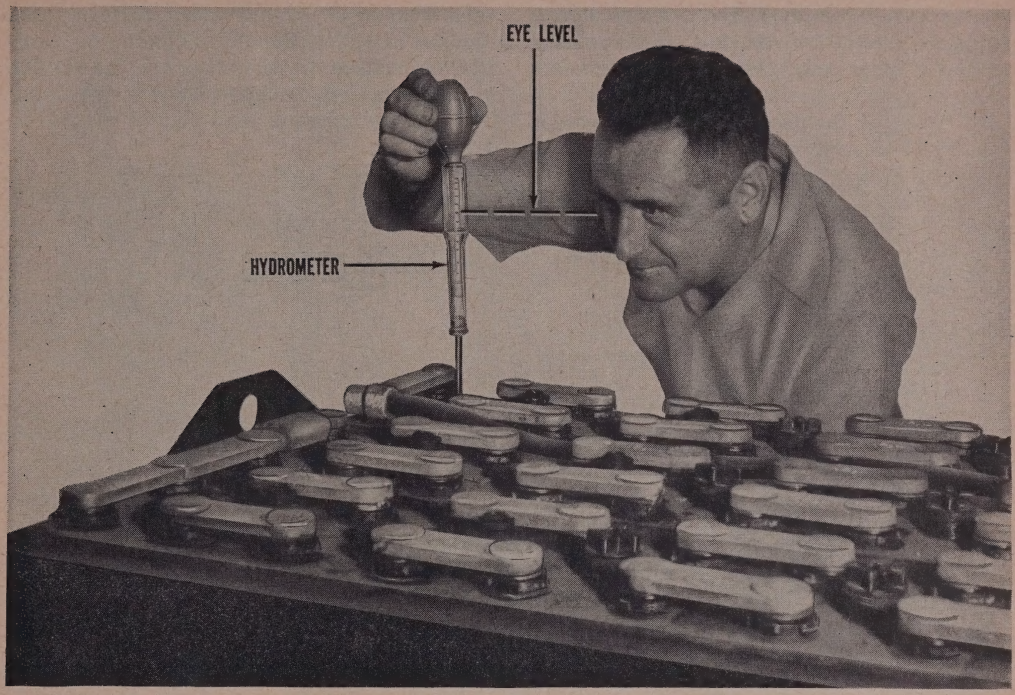


Figure 18. Taking specific gravity reading.

22. Adjusting Specific Gravity

When the corrected specific gravity of the electrolyte in a fully charged battery is lower or higher than the specific gravity range as set at the factory, adjustments should be made to the concentration of the electrolyte to correct the condition.

a. Raising Specific Gravity. An adjustment to correct a low specific gravity reading must be made only if charging does not raise the specific gravity of the electrolyte to the specific gravity attained at the end of the last equalizing charge and should be required only if electrolyte is lost through spillage or weakened by overfilling the cells with water. In this connection, consideration should be given to the fact that full-charge specific gravity decreases with the age of the battery. The adjustment should be made at the end of an equalizing charge and must never be made on a cell that does not gas. It consists of adding new electrolyte to the battery until the specific gravity of the electrolyte is normal. The strength of the electrolyte to be used depends upon the amount of correction required. To prepare electrolyte solution of any desired strength, mix sulphuric acid and distilled water in the proportion indicated by table XII. When mixing electrolyte, wear goggles, rubber gloves, and a rubber apron; and always pour the acid into the water, never the water into the acid. After mixing, allow the diluted solution to cool to 90° F. or lower. To correct a specific gravity deficiency of 0.015 or less, add electrolyte with a specific gravity of 1.265 to 1.300 to the battery instead of adding distilled water. To correct a specific gravity deficiency of more than 0.015, remove a quantity of old electrolyte and replace it with an equal amount of new electrolyte having a specific gravity of 1.325 to 1.400. After the adjustment is made, continue to charge the battery at the finishing rate for about 1 hour, then take a specific gravity reading. If the reading is still below normal, repeat the adjustment at the end of the next equalizing charge.

b. Lowering Specific Gravity. Steps should be taken to a lower fully charged specific gravity reading of more than 1.280 and must be taken to lower a fully charged specific gravity of 1.310. To lower the specific gravity, remove a quantity of electrolyte and replace it with an equal amount of distilled water. Normally, the removal of ⅛ inch of electrolyte and the addition of distilled water will lower the specific gravity 3 to 5 points. A specific gravity reading of 1.290, for example, may thus be reduced to 1.286.

Table XII. Proportions of Sulphuric Acid and Water

Specific gravity desired	Sulphuric acid of 1.835 specific gravity		Sulphuric acid of 1.400 specific gravity	
	Parts water required	Parts acid required	Parts water required	Parts acid required
1.375	1.78	1	.075	1
1.365	1.86	1	.11	1
1.365	1.94	1	.14	1
1.350	1.975	1	.16	1
1.340	2.08	1	.20	1
1.330	2.17	1	.24	1
1.325	2.22	1	.27	1
1.315	2.33	1	.31	1
1.310	2.42	1	.33	1
1.300	2.52	1	.38	1
1.290	2.65	1	.43	1
1.285	.270	1	.46	1
1.280	2.79	1	.49	1
1.275	2.84	1	.53	1
1.270	2.92	1	.56	1
1.260	3.10	1	.63	1
1.255	3.18	1	.67	1
1.250	3.26	1	.70	1
1.245	3.38	1	.74	1
1.240	3.46	1	.78	1
1.230	3.67	1	.85	1
1.225	3.80	1	.905	1
1.220	3.91	1	.96	1
1.215	4.03	1	1.00	1
1.210	4.15	1	1.05	1
1.205	4.26	1	1.11	1
1.200	4.43	1	1.16	1

23. Replacing Electrolyte

When electrolyte has been spilled from the cells of a battery, replace the electrolyte as follows:

a. Using an approved level gage, measure levels of electrolyte in cells from which electrolyte has been spilled.

b. Take specific gravity of electrolyte in surrounding cells.

c. Using table XII as a guide, prepare an electrolyte solution of approximately the same specific gravity as that in the surrounding cells; and refill all low-level cells. Do not overfill cells. Use distilled water if electrolyte is not available. Do not allow cells to remain unfilled; and do not refill with electrolyte of higher specific gravity than that in surrounding cells.

24. Cleaning

Batteries should be cleaned at least once every 6 months. To clean a battery, remove it from truck and proceed as follows:

a. See that all vent plugs are well seated, and remove the battery from the vehicle.

b. Prepare a solution of 1 pound of baking

soda to 1 gallon of water. Use this solution to wash the top of the battery. Rinse with clear water.

c. Use a scrubbing brush equipped with a wood handle and clean corroded or dirty battery terminals with soda solution. Rinse terminals with water (fig. 19), dry them, and apply a thin coating of petroleum jelly.

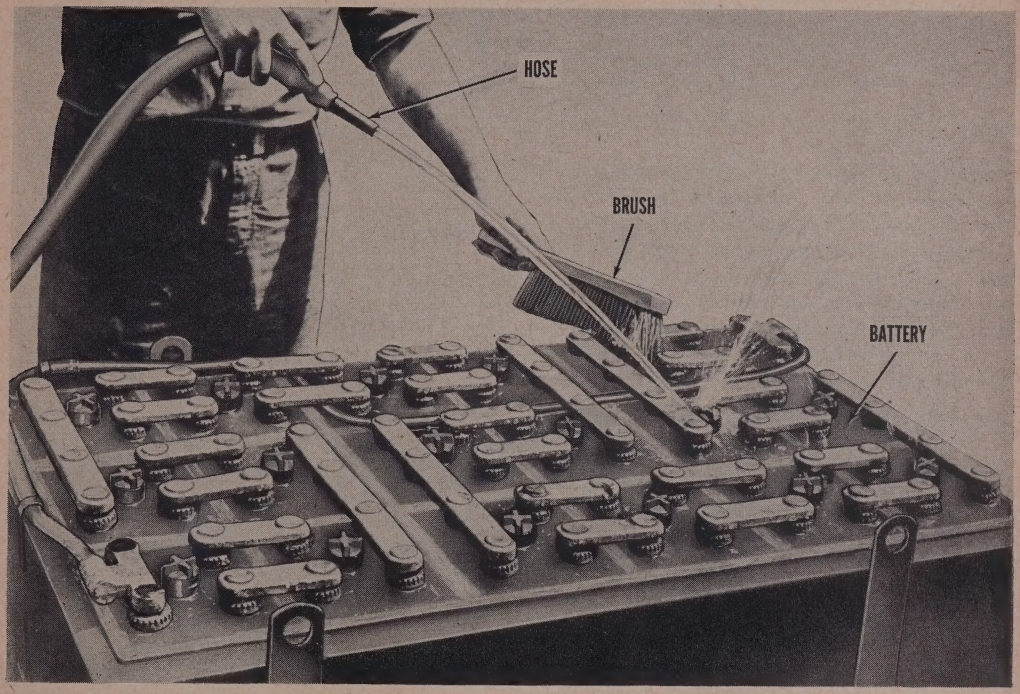


Figure 19. Cleaning lead-acid battery.

CHAPTER 3

REPAIR

25. General

Storage batteries that have become unserviceable before the expiration of their expected normal service life can be reclaimed by rebuilding if justified by time and labor costs. Rebuilding is justified whenever serviceable batteries can be obtained by assembling parts from two or more similar unserviceable batteries, or if a battery can be made serviceable by the repair of cell covers or containers or by the replacement of separators. Rebuilding is not justified if an unserviceable battery does not contain usable cells or parts. Containers, cell covers, groups, elements, connectors, and scrap lead should be reclaimed from unserviceable batteries. Reclaimed parts, however, should be retained in quantities sufficient only for rebuilding operations.

26. Tools and Equipment

Appendix II contains a list of tools and equipment necessary to repair batteries. This list is included for information only and is not to be used as a basis for requisitioning.

27. Lead Burning

Lead burning is the process of welding two lead parts together by means of a small acetylene torch or a carbon burning outfit.

a. Equipment. When available, an approved carbon-burning outfit (app. II) is used for lead burning. This outfit consists of a pencil-shaped rod held by a wood-handle-and-clamp device to which cables are attached. The ends of the cables are equipped with clips for attachment to cell terminals. The carbon-burning outfit operates by clipping the terminals across three cells of a storage battery in such a manner that a 6-volt potential is provided. When an approved carbon-burning outfit is not available, a substitute lead-burning tool may be improvised from the wooden handle of a scrap file or screwdriver and an 8-inch piece of $\frac{3}{8}$-inch copper tubing as follows:

(1) Using a $\frac{3}{8}$-inch drill, drill lengthwise through the wooden handle.

(2) Flatten one end of the copper tubing, solder an electrical wire to it, and insert the tubing through the wooden handle.

(3) Flatten the other end of the copper tubing for a distance of approximately $1\frac{1}{2}$ inches and turn back approximately half of the flattened portion to form an elongated loop.

(4) Using a $\frac{1}{8}$-inch drill, drill a hole through the end of the rolled back portion and through the adjacent flattened copper tubing.

(5) Insert the electrode from a flashlight battery through the loop in the copper tubing.

(6) Install a $\frac{1}{8}$-inch bolt, nut, and lockwasher through the holes drilled in the copper tubing and tighten until the electrode is clamped in place.

(7) Attach free end of wire extending from handle end of copper tubing to a spring clip and attach clip to terminal of battery. Connect a second lead, equipped with spring clamps, from the other terminal of the battery to the connector or terminal that is to be repaired.

b. Technique. Touch the lead burning tool to the connector or post to be burned. Do not use the tool as an arc welder. Work quickly while electrode is hot. Do not use for prolonged periods of time as too much lead will be melted.

28. Replacing Cell Cover

a. Exide Batteries.

(1) Remove electrolyte down to splash cover.

(2) Using a ¾-inch drill bit, drill cell connector centrally over each post to a depth of ¼ to ⅜ inch (fig. 20). Lift off cell connector with pair of pliers.

(3) Remove ceiling nuts and rubber gaskets.

(4) Unseal cell cover by running hot putty knife through sealing compound (oil asphalt) close to the inside of the jar. Do not insert knife deeply enough to break top edges of separators.

(5) Lift cell cover from cell by hand.

(6) Clean surface of jar wall and tray with a cloth moistened in soda solution; then wipe dry.

(7) Wipe surface of new cover with clean cloth and place new cover in position.

(8) Replace rubber gaskets and install seal nuts. Tighten seal nuts and stake them at 3 or 4 places with a center punch.

(9) Lay glass caulking cord (fig. 21) in bottom of sealing groove and press cord flat in bottom of groove with a blunt-pointed tool.

(10) Pour enough melted sealing compound (fig. 22) into sealing groove to fill it half full. If necessary, use a soft flame until compound adheres to jar walls and cover, then pour enough additional compound to fill groove all the way. Allow compound to cool. Clean off excess with hot putty knife.

(11) Replace petroleum jelly (heated) in wells at top of sealing nuts.

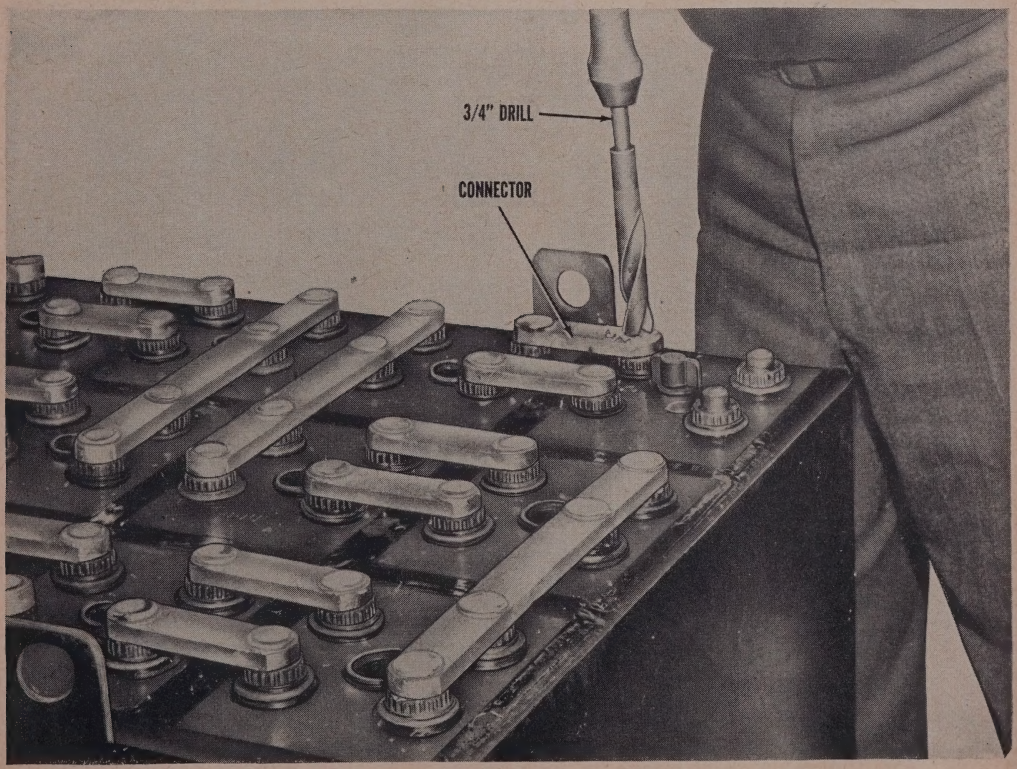


Figure 20. Drilling cell connector.

(12) Remove vent plugs from adjacent cells. Cover area of battery not being worked on with cloth saturated in water. Press cloth into vents of cells and pack area around vents with wet paste.

(13) Using a knife blade, clean both posts and the inside surface of the cell-connector eye. Place the cell connector in position and tap in place with a soft hammer.

(14) Using a very small acetylene torch, carbon-arc-burning outfit (Exide Part Number 20104), or lead-burning tool, melt the lead of the cell connector and the top of the post so that they run together (fig. 23). Add additional molten lead to fill connector eye.

Note. Never use soldering flux of any kind. If carbon-arc-burning outfit is used, wear dark glasses to protect eyes.

(15) Allow unit to cool. Remove excess lead with brush, file, or scraper.

(16) Remove water-saturated cloths or packing from battery. Install vent plugs in all cells except repaired cell.

(17) Add distilled water or electrolyte to repaired cell to bring electrolyte to proper level. Install vent plug.

b. Gould and C & D Batteries.

(1) Remove electrolyte down to separators.

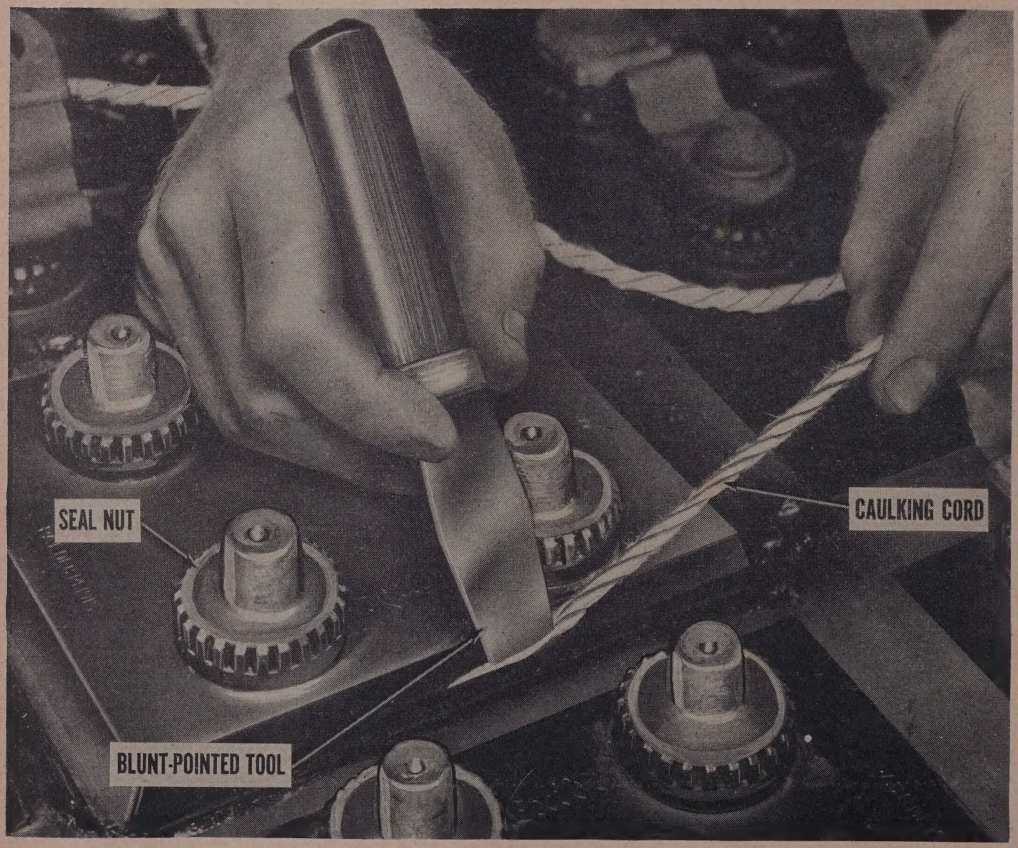


Figure 21. Installing caulking cord in Exide cell.

Figure 22. Pouring sealing compound in seal grooves.

(2) Using a $^{15}/_{16}$-inch drill bit, drill cell connector centrally over each post to a depth of $^{3}/_{8}$ inch.
(3) Lift off cell connector (fig. 24).
(4) Unseal cell cover with hot putty knife as described in *a*(4) above.
(5) On Gould batteries, which are equipped with lead - insert - type covers, cut off the post extension above the cover at all posts. Make certain that lead burns between posts and lead inserts in cover are broken. Use lead insert mold (Gould Part No. P–77016) for this purpose by placing it around post and tapping lightly with hammer. Using L-shaped tool, remove cover

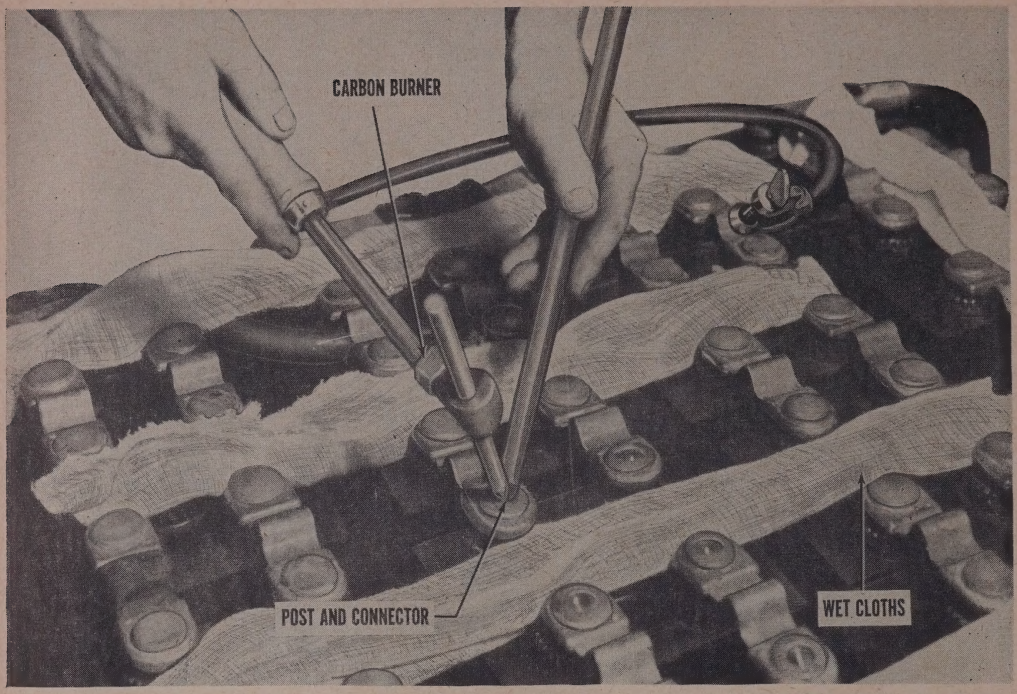


Figure 23. Burning cell connector with carbon-burning outfit.

from cell. On C & D batteries, which are equipped with sealing nuts, remove sealing nuts and gaskets from terminal posts and then remove cover from cell by hand.

(6) Install new cover on Gould cell as follows:

(*a*) Place post mold (Gould Part No. P–77013) firmly on post and allow it to extend down about $\frac{3}{16}$ inch. Small-diameter hole is top of mold.

(*b*) With wet rags protecting adjacent cells, use a small acetylene torch, carbon-arc-burning outfit, or lead-burning tool and melt top of post, adding new lead until post mold is filled flush to top (fig. 25). Allow lead to cool before removing mold.

(*c*) Place new cover in position and burn post to lead insert of cover (fig. 26) using post mold (Gould Part No. P–77013).

(*d*) Place cell connector in position and burn to post. After union has cooled, place bottom mold (Gould Part No. P–77015) on top of connector and repeat burning process.

(*e*) Remove water-saturated rags. Install vent plugs on all except repaired cell.

(*f*) Reseal cover with melted compound. Add distilled water or electrolyte to bring electrolyte to proper level in repaired cell. Install vent plug.

(7) Install new cover on C & D cell as follows:

(*a*) Place new cover in position and install sealing nuts and gaskets.

(*b*) Seal cell cover in place with melted compound.

(*c*) Replace cell connectors as described in *a*(14) above.

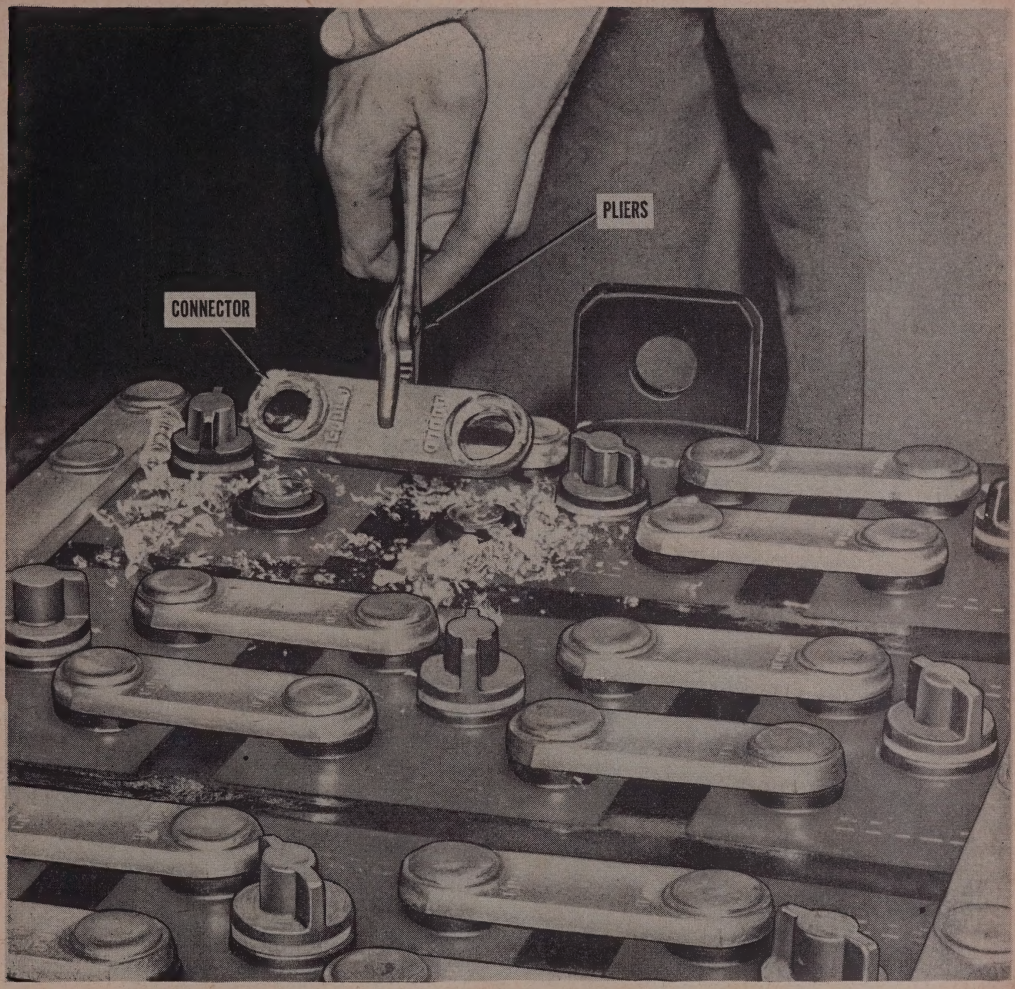


Figure 24. Lifting cell connector from Gould battery.

(*d*) Add enough electrolyte or distilled water to bring electrolyte in repaired cell to proper level above plates.

29. Replacing Jar

If a jar should become broken, do not allow plates or separators to dry, but remove the cell from the battery at once and immerse the plates and separators in a nonmetallic vessel containing distilled water. The entire element may be left under water for approximately 1 week, but for longer periods the positive plates should be withdrawn and allowed to dry until used.

a. Exide Batteries.

(1) Remove electrolyte down to splash cover.

(2) Remove cell connector (par. 28*a*(2)).

(3) Unseal jar from adjacent jars in tray.

(4) Lift cell out of tray (fig. 27). Cells with 13 plates may be lifted manually;

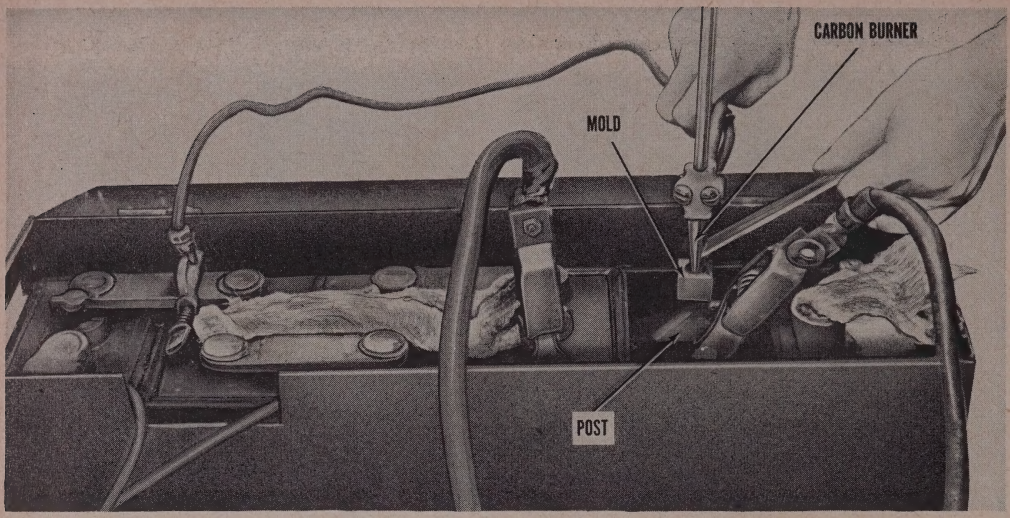


Figure 25. Building up post with carbon burner.

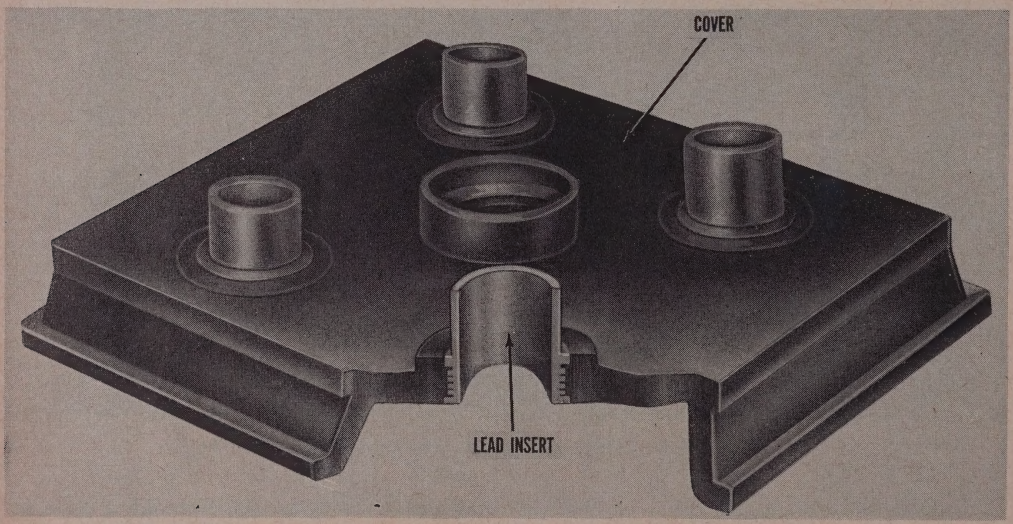


Figure 26. Lead insert of Gould cell cover.

cells with 19 or 25 plates will have to be lifted with a crane or hoist.

(5) Unseal the cell cover (fig. 28) following instructions in paragraph 28*a*(4). Do not remove cover if it is in good condition.

(6) Lift element and cover out of jar. Elements with 13 plates can be lifted manually (fig. 29) with the use of chain holddowns (Exide Part Number 32345). Large-size elements must be removed with a hoist. Use wood clamp on outside of negative plate to prevent plates from fanning and separators from dropping out.

Note. If element should stick in jar, place cell in hot water to within 1 to 2 inches of top of jar. This will temporarily expand and soften the rubber, allowing element to be withdrawn. Do not allow element to dry or be exposed to air for long periods of time. Sprinkle with water or cover with wet cloths.

(7) Examine element for damaged separators. Replace those that are cracked or broken as follows:

(*a*) Place element, with cover attached, on edge.

(*b*) Remove old separators and insert new ones from bottom. Make certain they are pushed all the way up and that they project equally on each side of the plates.

(8) If jar has been leaking, prepare tray to receive cell by washing space in tray left by jar with soda solution; then rinse and wipe dry.

(9) Grip or clamp element near bottom in order to prevent plates from flaring out and insert element in jar. Do not let outside plates start down over outside of jar.

(10) If leak in old jar was near top, fill cell with electrolyte of 0.040 point higher than surrounding cells. If leak was near bottom, use electrolyte 0.080 point higher.

(11) Reseal cell and place jar in tray with proper polarity; reburn cell connectors to posts (par. 28*a*(13)–(16)).

(12) Charge battery until repaired cells(s) gases freely and until three consecutive half-hourly hydrometer readings show no increase in specific gravity. If specific gravity in repaired cell(s) differs more than 0.010 from that of surrounding cells, make specific gravity adjustment (par. 22).

b. Gould and C & D Batteries.

(1) Remove electrolyte down to separators.

(2) Remove cell connectors by cutting the connector with a saw immediately above the space where the two jars join.

(3) Unseal the jar from adjacent jars and lift from tray. It may be necessary to use penetrating oil or kerosene mixed with regular oil as a lubricant if the

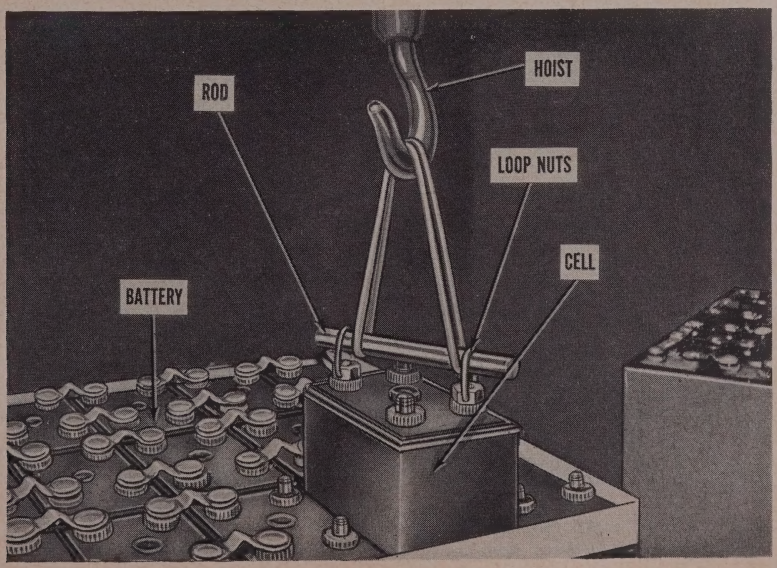


Figure 27. Removal of Exide cell from tray.

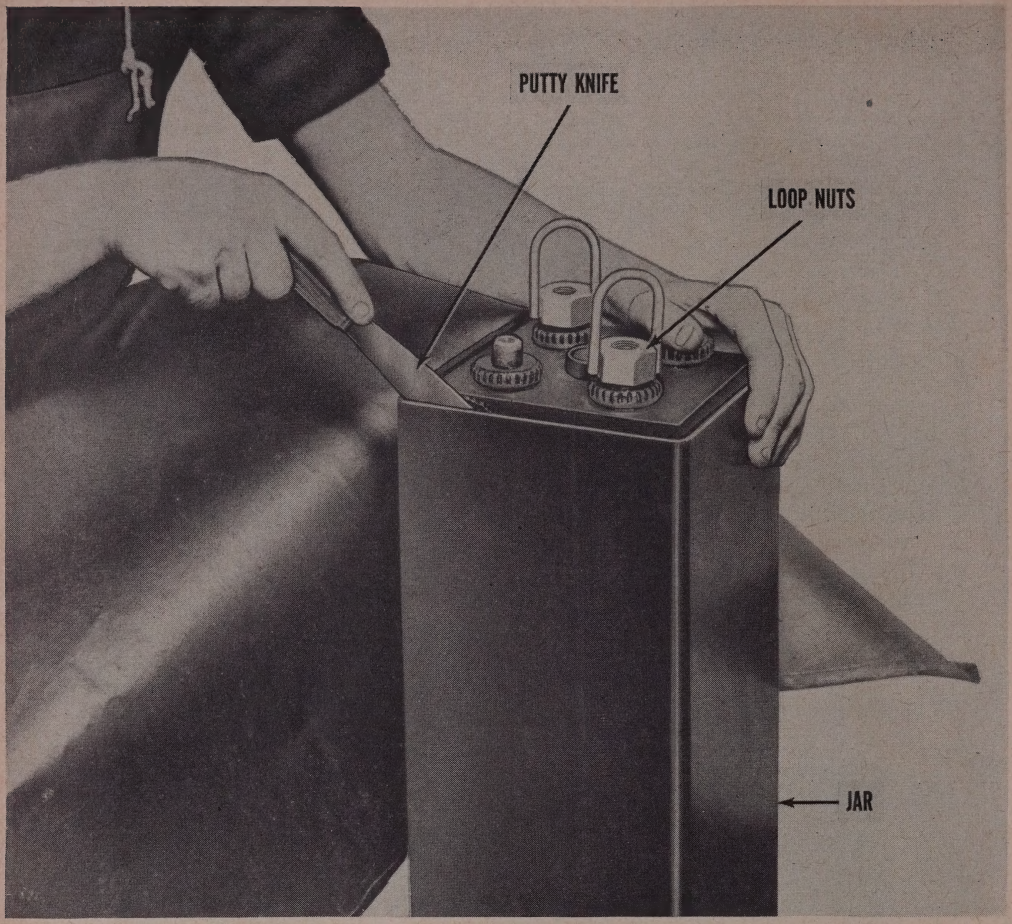


Figure 28. Unsealing individual Exide cell cover.

jar is tight. Small cells may be lifted by hand with use of a vise-grip wrench or special post trimmer (Gould Part No. Z–1265), which should be placed on negative post. Large cells must be lifted by means of a hoist.

(4) Unseal cell cover with hot putty knife (par. 28*a*(4)). It may be necessary to heat jar on all 4 sides with a soft flame.

(5) Lift element and cover about halfway out of cell and allow it to remain in this position for about 2 minutes to let electrolyte drain into jar. Use wood clamps on negative plates to keep element intact. If element to be removed contains 13 plates, use jar holddowns and vise-grip wrench or post trimmer (fig. 30). For large elements it will be necessary to use a hoist.

(6) If Gould cell cover is to be reused, use special drill (Gould Part No. 35459–C) which fits over the post extension to cut the weld between the connector and the lead insert of the cover. Then lift off cover with L-

Figure 29. Pulling element from Exide cell.

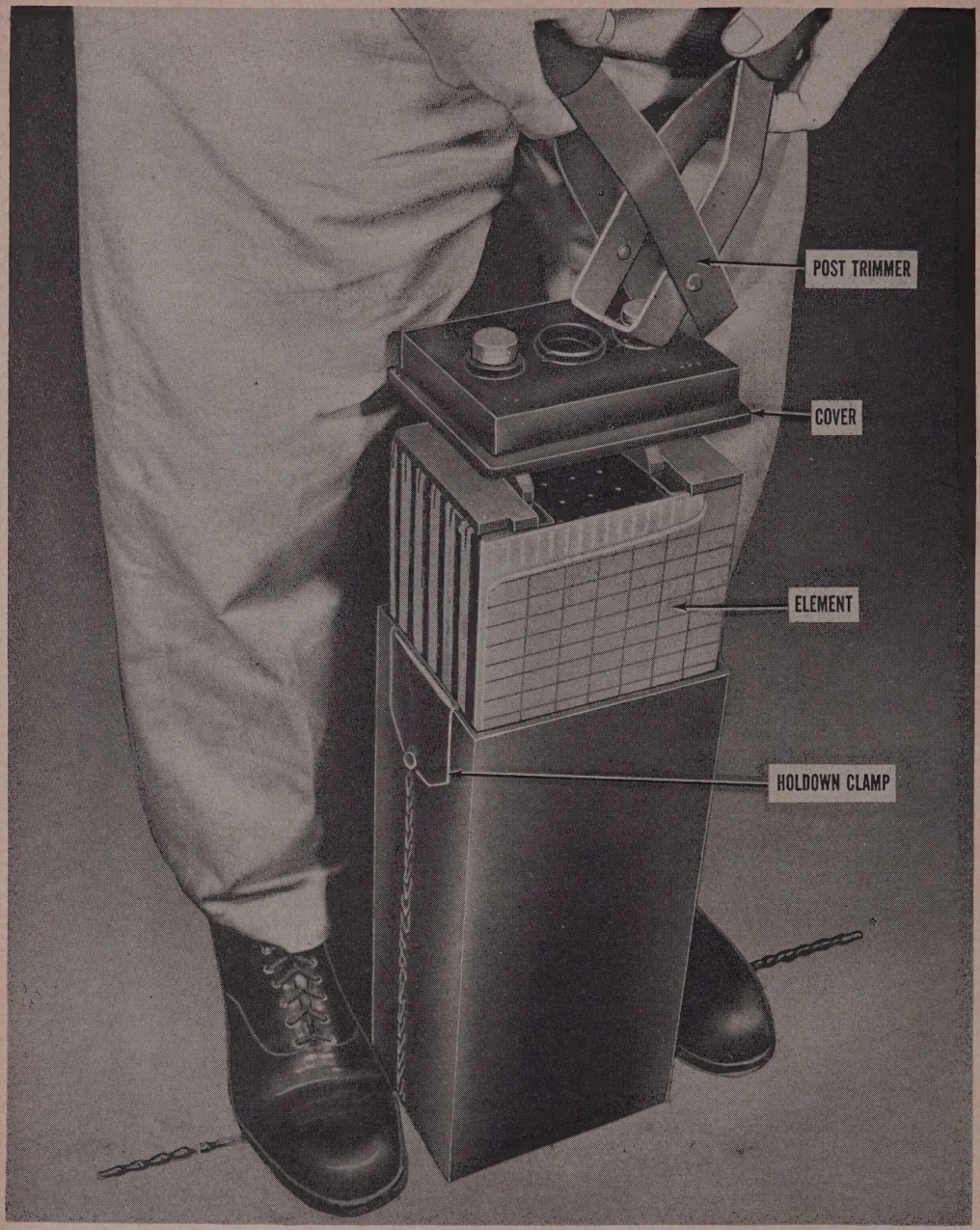


Figure 30. Removing element from Gould cell.

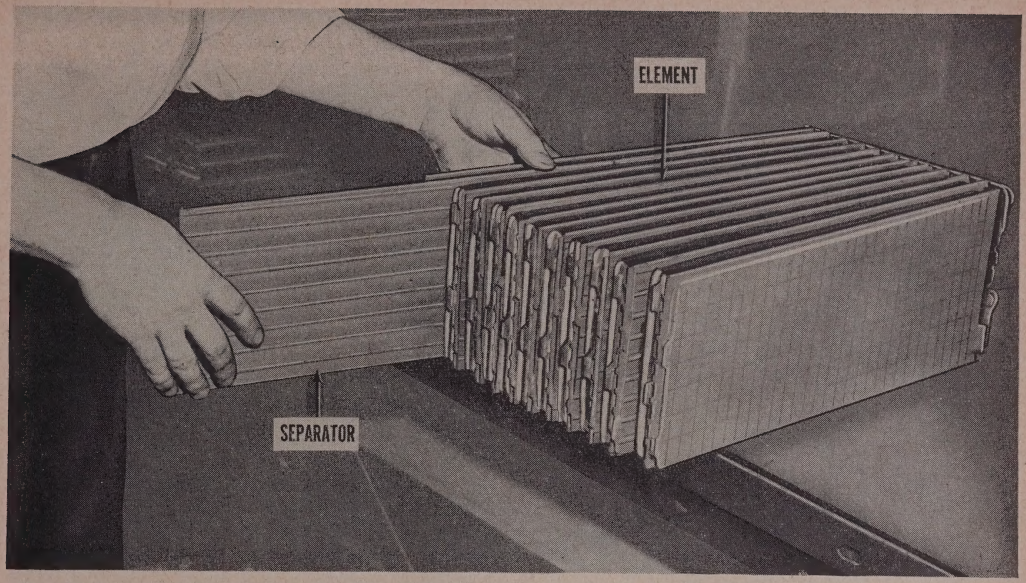


Figure 31. Replacing separators in Gould element.

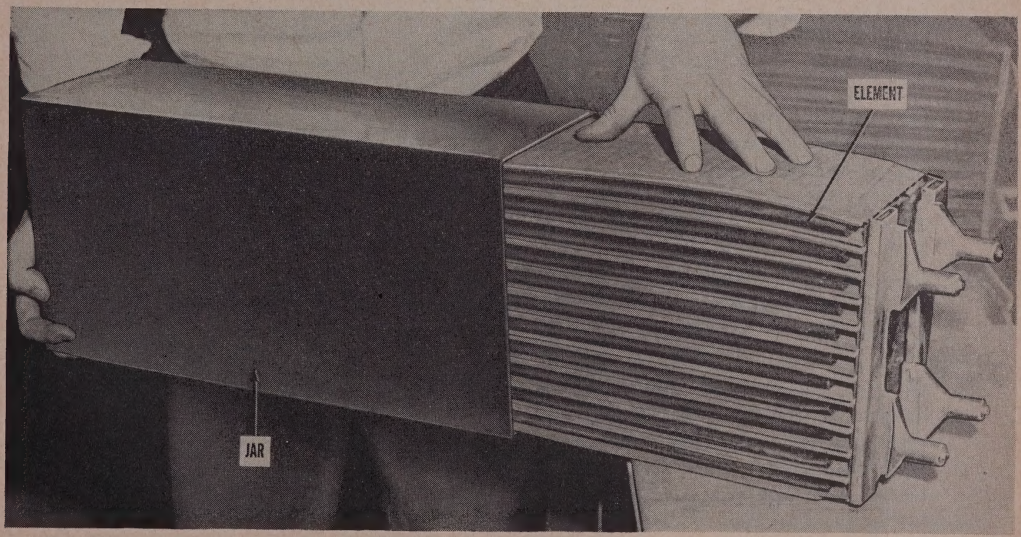


Figure 32. Starting Gould element into jar.

shaped tool. If cover is not to be reused, cut post extension and remove cover as described in paragraph 28*b* (5). Do not remove C & D cover from element unless cover is to be replaced.

(7) Place element on wood surface, negative plate down.

(8) If necessary, replace separators (fig. 31). Remove separators at each end of element, then work toward center; install separators in center of element, then work toward each end.

Note. Do not let element to be exposed to air any longer than necessary. If element starts to heat, sprinkle with water or cover with a wet cloth.

(9) Install element as shown in figures 32 and 33. Make certain that ribs are in place at bottom of jar and that element is placed squarely in position.

(10) Replace cover on Gould cell. Method of replacing cover will depend upon method of removal. If cover was removed with posts in place, install cover and then burn post to lead insert of cover (par. 28*b*(6)). If cover was removed with posts out, install cover, build up post, and then burn post to lead insert of cover (par. 28*b*(6)).

(11) Reseal cell with hot sealing compound and remove all excess compound that may have run down outside of jar. Fill cell to correct level with electrolyte of 1.268 to 1.280 specific gravity.

(12) Give cell an equalizing charge and adjust specific gravity (par. 22), if necessary.

(13) Place cell in tray and seal in position with hot sealing compound.

(14) Remove vent caps from surrounding cells and cover cells and vent holes with damp cloths. Splice intercell connectors as follows:

(*a*) Place special connector mold under connector and support both sides with small wedge. Put stop in place (fig. 34).

(*b*) Using carbon burner, add molten lead until connector is level. Allow lead to cool. Remove mold and wet cloths.

(15) Recheck electrolyte level and bring to correct height by adding electrolyte of same specific gravity as in surrounding cells.

(16) Charge battery until cell is completely charged. Make specific gravity adjustment (par. 22), if necessary.

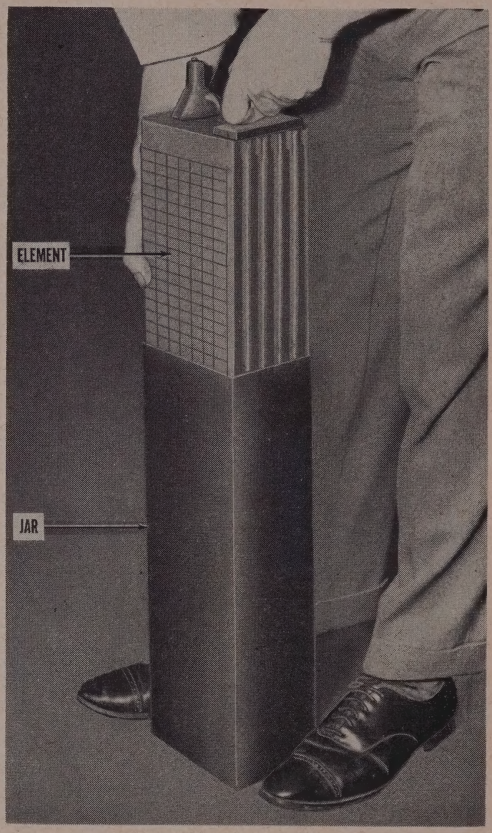


Figure 33. Seating Gould element in jar.

30. Restoring Sulphated Batteries

If sulphation has not progressed too far, it may be possible to restore the battery to service in one of the following ways:

a. Water Treatment.

(1) Using an appropriate chain hoist and sling, carefully invert battery and dump electrolyte over a floor drain. If

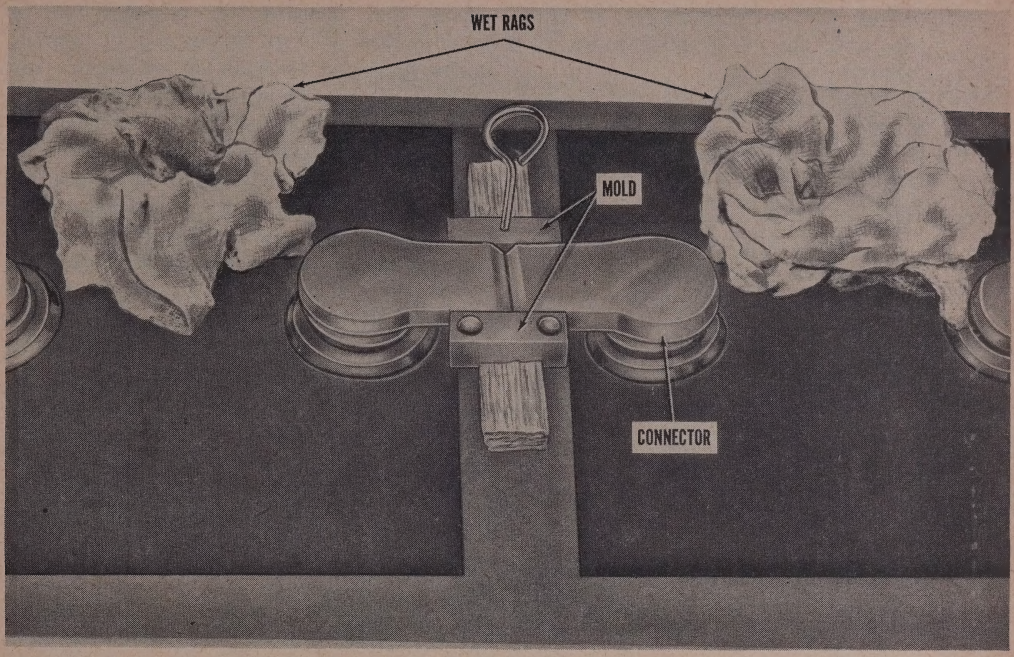


Figure 34. Spliced Gould cell connector.

dumping is not possible, it may be necessary to remove each cell and dump it individually.

(2) Fill cells with distilled water and allow battery to stand for several hours.

(3) Charge battery at low rate, 5 to 10 amperes, taking frequent hydrometer readings of each cell to determine whether charge is taking effect. If so, continue charging at low rate for as long as specific gravity in any cell shows an increase. Take frequent temperature readings of each cell and discontinue charging temporarily if cell temperatures reach 110° F. It will be possible to take specific gravity readings because the distilled water that was put into the cells will become electrolyte as sulphate is broken down at the plates.

(4) If specific gravity at the end of a prolonged charging period (24 to 48 hours) remains constant at too low a value (below 1.275), make specific gravity adjustment (par. 22*a*) to bring specific gravity to at least 1.275–1.300. Subsequent changes should further restore full charge readings.

b. Cycling.

(1) Charge battery at low rate, taking frequent specific gravity readings of each cell to determine whether charge is taking effect. If so, continue charging at low rate, carefully watching cell temperatures, until specific gravity shows no increase (usually 24 to 48 hours).

(2) If battery was not brought to full-charge specific gravity, discharge the battery by connecting some lamps or other resistance across terminals. Use enough resistance to draw a discharge current equal to $\frac{1}{10}$ the ampere-hour capacity of the battery. Discharge battery until cell voltage drops to 1.75 volts.

(3) Charge battery immediately at low rate until specific gravity shows no increase.

(4) Discharge battery as described in (2) above.

(5) If battery does not respond to 2 or 3 cycles (72 to 96 hours), it is sulphated to point at which a complete rebuild is necessary.

Note. Do not cycle a battery that can be brought to full-charge specific gravity by a single charge and specific gravity adjustment.

31. Troubleshooting

Table XIII indicates the symptoms, probable causes, and remedies for common battery troubles that develop during routine service. If the suggested remedies do not correct the condition, it may be assumed that the battery is defective because of such conditions as buckled plates, complete sulphation, hardened negative plates, soft active material on positive plates, grid corrosion, loss of active material or excessive self-discharge (local action), and it will be necessary to disassemble the battery to inspect elements and plates. If such conditions are found, they can be corrected only by complete rebuild, and must be reported to the designated person in authority.

Table XIII. Storage Battery Troubleshooting Chart

Symptom	Trouble	Cause	Remedy
Specific gravity low after charge.	Weak electrolyte	Overfilling with distilled water.	If all cells gas on charge, make specific gravity adjustment (par. 22*a*). Do not make adjustment on cells that do not gas.
	Shorted plates	Excess sediment in bottom of cell, impure electrolyte, foreign matter in cell.	Use hydrometer to locate defective cell(s). Remove and disassemble defective cell(s). Replace separators and electrolyte. Remove sediment and wash sediment space.
	Broken jar	Careless handling	Replace broken jar (par. 29).
Cell or battery does not gas on charge.	Sulphation	Overcharging or overdischarging.	Subject cell or battery to water treatment or cycling (par. 30*a*).
	Shorted plates	Excess sediment in bottom of cell or impure electrolyte.	Continue charging at finishing rate until specific gravity shows no increase and then for 3 hours more. If cell still does not gas, remove cell from battery. Disassemble cell and check for excess sediment. Remove sediment, replace electrolyte, and replace separators.
	Reversal of polarity	Battery improperly connected to charger.	If reversal has existed for only a short time, discharge battery through resistance at normal rate and recharge immediately at regular rate until specific gravity shows no increase. If specific gravity is low but all cells gas, make specific gravity adjustment (par. 22*a*).
Cell overheats on charge.	Sulphation	Overcharging or overdischarging.	Replace element.
Battery will not retain charge.	Sulphation, shorted plates, clogged separators, or cracked jar.	Overcharging or overdischarging, improper handling.	Use hydrometer to locate defective cells. Remove and disassemble defective cells. Replace separators, if necessary; remove sediment; replace broken jars. Replace cell or battery if sulphation is excessive.

Symptom	Trouble	Cause	Remedy
Specific gravity high after charge.	Too strong electrolyte	Adding too high specific gravity electrolyte when replacing spillage or when making specific gravity adjustment.	Make specific gravity adjustment as outlined in paragraph 22*b*.
One cell requires more frequent additions of distilled water.	Broken jar	Improper handling	Remove cell from battery and replace jar.

32. Correcting Self-Discharge

Self-discharge is a normal occurrence that takes place in charged batteries. When a battery is charged, a small amount of lead-antimony dissolves from the positive-plate grid and is deposited at the negative plate. This sets up a local electrochemical reaction which causes gradual discharging at the negative plate. The normal rate of self-discharge in a fully charged battery at normal temperatures averages about 0.001 point specific gravity each day. The rate is greater, however, and faster at higher temperatures and in fully charged batteries (table XIV). Excessive self-discharge may be caused by defective separators or by excessive sediment deposits in the sediment space at the bottom of battery cells. In some instances, this condition, which resembles shorted plates, may be remedied by replacement of separators.

Table XIV. Temperature Effect on Battery Self-Discharge

Temperature	Loss of specific gravity per day
120° F.	.004
100° F.	.003
80° F.	.001
50° F.	.0005

CHAPTER 4
STORAGE AND SHIPMENT

33. Storage Methods

a. Limited. Lead-acid storage batteries may be stored charged and wet (filled with electrolyte) for limited periods of time (usually 90 to 120 days), or if they are being used for standby, or auxiliary, service. When stored in this manner, batteries must be kept fully charged by periodic routine charges (par. 18*a*) or by continuous charging at a rate less than 1 ampere per positive plate (trickle charge) to restore self-discharge. Hydrometer readings and electrolyte-level checks must be made weekly and distilled water added when necessary. After water has been added, the trickle charge must be continued to thoroughly mix water with electrolyte. It will also be necessary to administer a booster charge (par. 18*c*) when specific gravity at 80°F. drops to 1.225 points.

Note. In tropical areas, if electrolyte has been diluted, specific gravity may drop to 1.140 points before booster charge is needed.

b. Extended. New or reconditioned lead-acid storage batteries should be stored charged and dry. Batteries in this condition can remain in storage unattended for a period of at least 2 years. They should then be filled and charged. Temperature during storage should not be below 32°F. or above 110°F. Care must be taken to see that batteries are not stored near radiators, hot-air ducts, or other sources of heat. If possible, batteries should be shielded from direct sunlight, particularly in hot climates.

34. Shipment

a. Charged and Dry Batteries. Depots will normally make domestic and oversea shipment of new or reconditioned lead-acid storage batteries in a charged and dry condition. Sufficient quantities of electrolyte will be shipped in accompanying carboy lots. Batteries and electrolyte intended for oversea shipment must be packaged in accordance with approved methods (TM 38–230).

b. Charged and Wet Batteries. Depots or using organizations may make shipments of lead-acid storage batteries in a charged and wet condition if intended for use within 30 to 90 days. Approximate shipping weights and cubages appear in table XV. Special care must be taken to see that the battery is fully charged and properly protected when crated. A tag should be attached to the crate showing the date of charge and specific gravity at completion of charge. Special attention should also be given by the receiving organization to the need for a freshening charge before the battery is put into service.

Table XV. Approximate Shipping Weights and Cubages for Lead-Acid Batteries

Battery and model numbers	Shipping weight		Shipping cubage including crate
	Wet	Dry	
	Pounds	Pounds	Cubic feet
C & D:			
18CDS13	1,740	1,485	20
18CDS19	2,420	2,044	22
18CDS25	3,217	2,722	30
Exide:			
18TLM13	1,470	1,241	20
18TLM19	2,153	1,811	22
18TLM25	2,774	2,311	30
Gould:			
18XLZ13	1,590	1,360	20
18XLZ19	2,300	1,940	22
18XLZ25	2,970	2,510	30

PART TWO

NICKEL-IRON-ALKALINE STORAGE BATTERIES

CHAPTER 5

INTRODUCTION

Section I. GENERAL

35. Scope

Part two of this manual contains information concerning the theory, operation, charging, and maintenance of 30-cell, 36-volt, nickel-iron-alkaline storage batteries used for motive power in electric-powered forklift trucks, warehouse tractors, and industrial cranes. Table XVI identifies and itemizes characteristics for all nickel-iron-alkaline batteries described in this manual.

Table XVI. Nickel-Iron-Alkaline Storage Batteries for Materials Handling Equipment

Manufacturer	Quartermaster stock number	Ampere-hour capacity	Cells	Plates per cell		Model number
				Positive	Negative	
Thomas A. Edison, Inc.	17–B–8310	281	30	5	6	C5
	17–B–8315	450	30	8	9	C8
	17–B–8320	600	30	8	9	D8

36. Forms, Records, and Reports

The following forms will be used by personnel responsible for the receipt, storage, operation, charging, and maintenance of nickel-iron-alkaline storage batteries. These forms will be prepared and maintained in accordance with instructions set forth in paragraph 2 and in appropriate Army regulations governing their use.

a. DD Form 6, Report of Damaged or Improper Shipment.

b. DA Form 468, Unsatisfactory Equipment Report.

c. DA Form 10–161, Monthly Storage Battery Record.

Section II. DESCRIPTION

37. Battery

Motive-power nickel - iron - alkaline storage batteries for electric-powered forklift trucks, warehouse tractors, and industrial cranes consist essentially of 30 cells, wood trays into which cells are assembled, a steel cradle into which trays are assembled, and the intercell and intertray connectors and components necessary to secure and protect the cells and provide necessary electrical interconnections (fig. 35). The battery is then identified by a series of numbers and letters that indicate the number of cells, the type of cells, and the number of positive plates per cell. The designation 30 C8, for example, indicates that the battery contains 30 cells of the C type with 8 positive plates per cell.

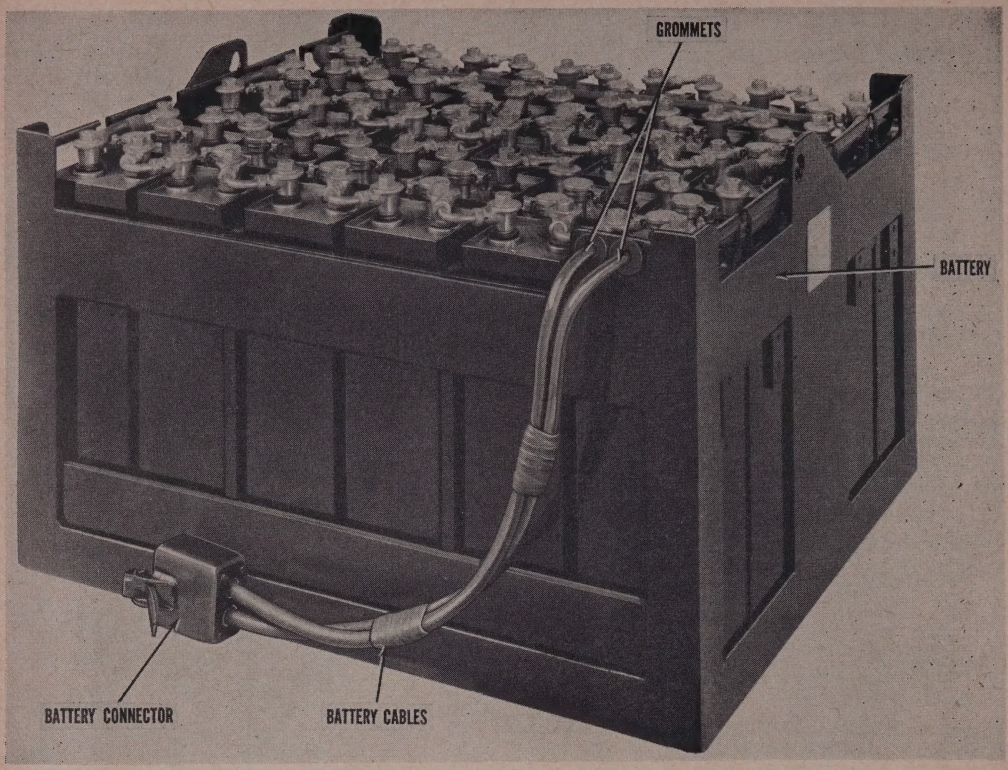


Figure 35. Nickel-iron-alkaline storage battery for motive-power service.

a. Cradle Arrangement. The cradle is a steel container into which the trays are assembled to form the battery. Normally, cells are arranged in 5 trays of 6 each and are connected in series so that the total voltage of the battery is the voltage of a single cell multiplied by the total number of cells, while the capacity is that of a single cell (par. 38). The voltage of a 30 C8 battery, for example, is 36 volts (1.2 volts per cell times 30 cells); the capacity is 450 ampere-hours (56.25 ampere-hours per positive plate times 8 positive plates). Typical battery data appear in table XVII; and a typical complete assembly for a CM5, C8, or D8 battery appears as figure 36. All nickel-iron-alkaline motive-power storage batteries for materials handling equipment are equipped with 30-inch connector cables.

Table XVII. Complete Assembly Data for Nickel-Iron-Alkaline Batteries

Cell type	Cradle specifications				Ampere hours	Voltage
	Length	Width	Height	Weight		
	Inches	Inches	Inches	Pounds		
C5	31½	24⅛	22⅜	964	281	36
C8	36½	31¼	22⅛	1440	450	36
D8	37	31⅝	29⅛	1953	600	36

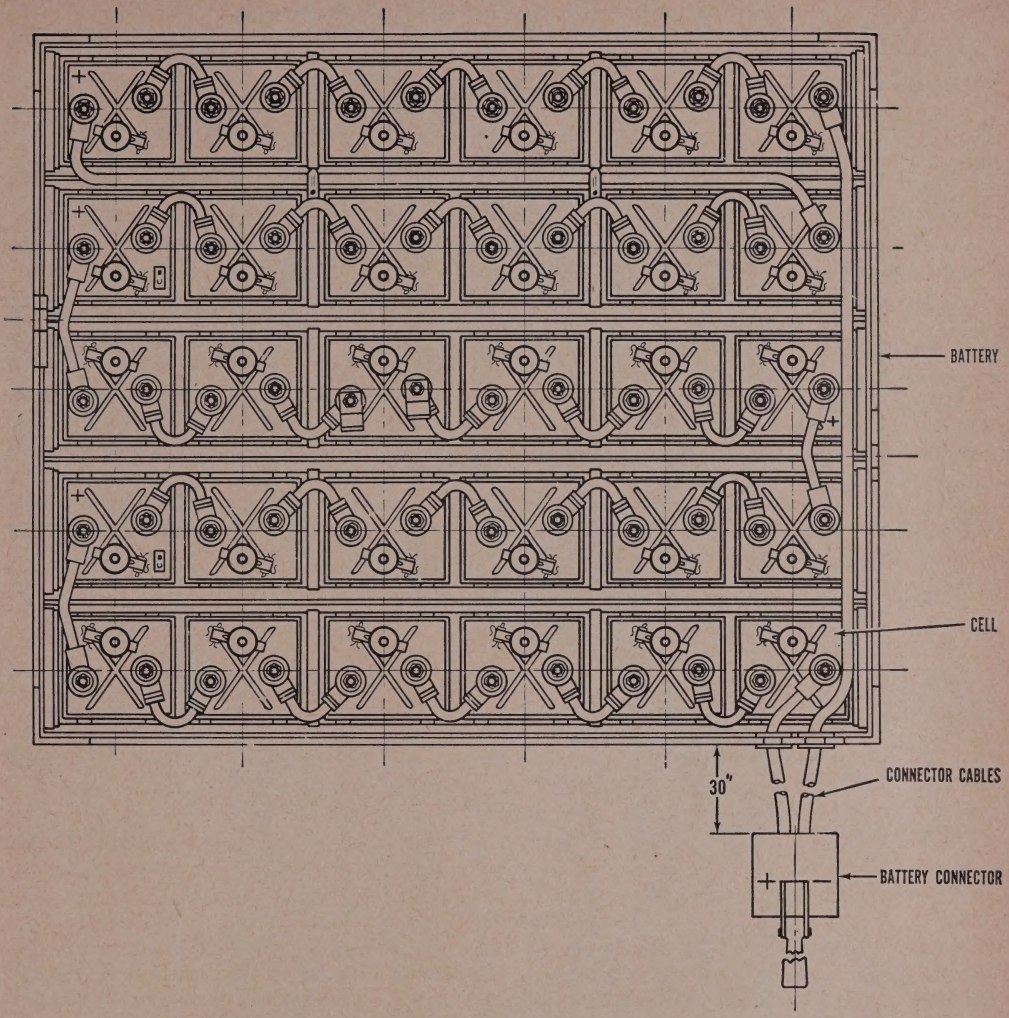


Figure 36. Typical complete layout for nickel-iron-alkaline storage battery.

b. Tray Specifications. A tray is a hardwood device into which 6 cells are assembled. Steel suspension bosses, spot-welded to the sides of the containers, fit into hard-rubber buttons recessed in the tray slats. Connection between cells is by means of solid copper connectors and jumpers made of copper sweated into steel lugs (app. IV). Each tray is removable after intertray connections and holddown plates have been removed. Tray specifications appear in table XVIII.

Table XVIII. Tray Specifications, Nickel-Iron-Alkaline Batteries

Cell type	Length	Width	Height	
			Fillercap closed	Fillercap open
	Inches	Inches	Inches	Inches
C5	23 7/16	6 1/8	20 3/16	21 23/32
C8	35 7/8	6 1/16	20 1/2	21 23/32
D8	36 1/4	6 1/8	27 7/32	28 11/32

38. Cell

The cell (fig. 37) is the fundamental unit of the battery. It consists of a steel container that houses the cell element. The type and capacity of the cell (and the battery) is determined by the number and size of tubes in each positive plate and is identified by the letter C or D. C-type positive plates, for example, contain 45 tubes and have a capacity of 56.25 ampere-hours per positive plate. A C5 cell or battery, therefore, has a capacity of 281 ampere-hours (56.25 ampere-hours x 5 positive plates). A C8 cell or battery which contains 8 positive plates, has a capacity of 450 ampere-hours. D-type positive plates contain 60 tubes and have a capacity of 75 ampere-hours per positive plate. A D8 cell or battery, therefore, has a capacity of 600 ampere-hours (75 ampere-hours x 8 positive plates). Cell specifications appear in table XIX.

Table XIX. Cell Specifications, Nickel-Iron-Alkaline Batteries

Battery	Cell dimensions			Cell weight	
	Length	Width	Height	Unassembled	Assembled *
	Inches	Inches	Inches	Pounds	Pounds
C5	3.24	5.13	19.16	27.2	29.3
C8	5.22	5.05	19.59	40.9	45.5
D8	5.22	5.13	26.27	54.8	60.0

* Assembled in tray and including electrolyte.

a. Element. The cell element, consisting of groups of positive and negative plates, rests, in an electrolyte solution consisting of 21 percent potassium hydroxide and a small amount of lithia in distilled water. In nickel-iron-alkaline batteries, the electrolyte provides a conducting path for the current that flows through the cell. The electrolyte in a fully charged cell has a specific gravity of approximately 1.200 at 60°F. Because the electrolyte is only slightly affected by electro chemical reactions within the cell element and serves only as a carrier for the electric current produced as a result of these reactions, a specific gravity reading does not indicate the state of charge of a nickel-iron-alkaline cell. The reading, which is taken by means of a hydrometer, simply indicates whether a renewal of electrolyte is necessary. *The state of charge of a nickel-iron-alkaline battery must be made with a charge test fork.* The top of each cell is fitted with a nickel-steel cell cover that is welded into place. Soft rubber bushings, (stuffing box gaskets), expanded by steel rings and hard-rubber screw washers (gland caps), insulate the pole pieces where they extend through the cover (app. IV). The filler valve body, through which electrolyte and water may be added, is located in the center of the cover. A steel spring is used to hold the fillercap completely open or closed. A hard-rubber valve, suspended from the fillercap, seats by gravity when the cap is closed, permitting the

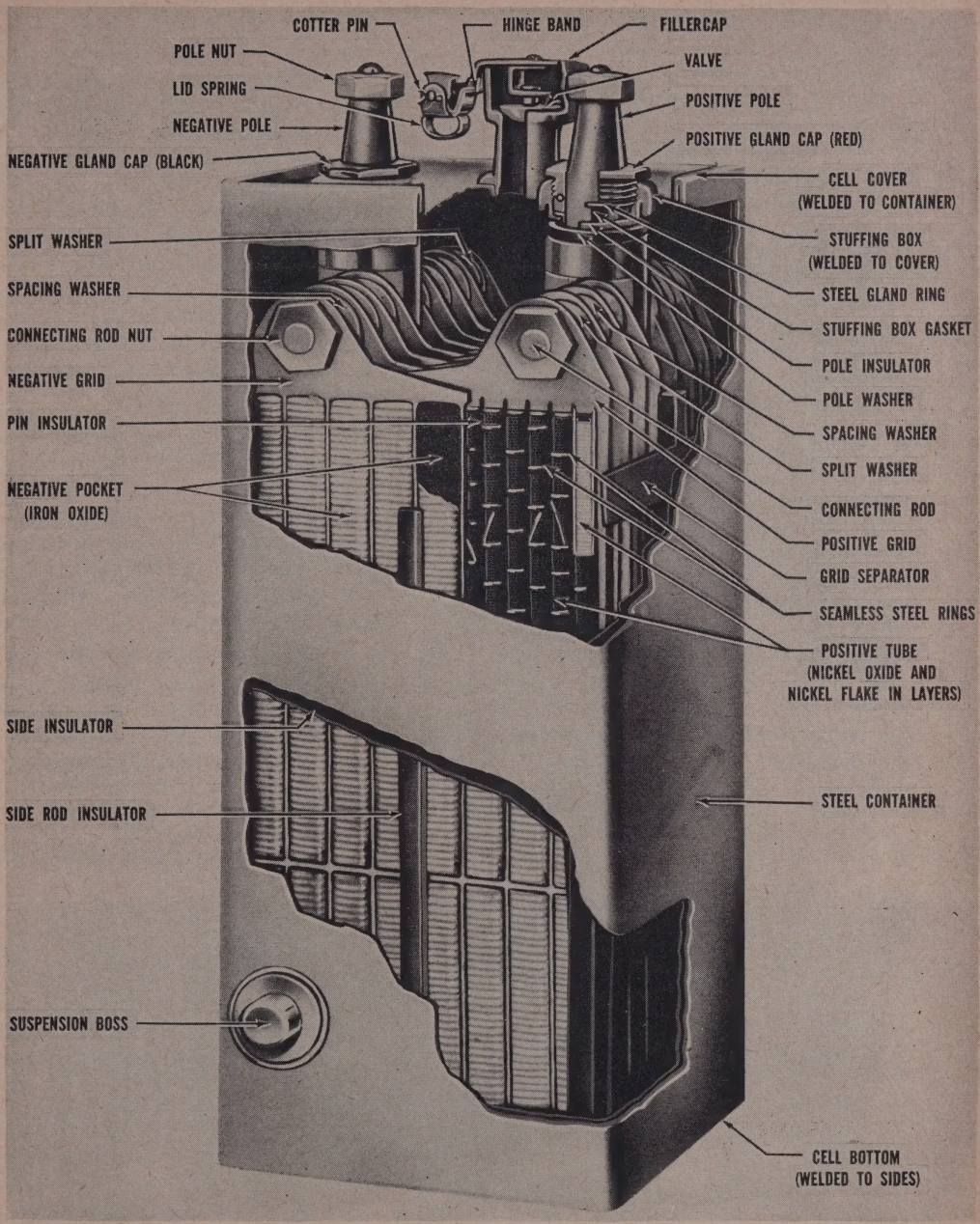


Figure 37. Cutaway view of nickel-iron-alkaline battery cell.

escape of gas and reducing evaporation. The positive terminal of the cell is identified by a red gland cap and a plus (+) mark embossed on the cell cover. The negative pole is identified by a black gland cap.

b. Groups. The positive and negative groups of plates that comprise a cell element are assembled by passing a connecting rod through holes at the tops of the plate grids. Steel washers are used to obtain proper spacing, one of the spacers being the base of the pole piece. A connecting rod nut is drawn up tight at each end of the connecting rod. The negative group always contains one more plate than the positive group so that both outside plates are negative. Rubber sheets insulate the outside negative plates from the sides of the container, while the edges of the plates are insulated from the bottom and the other sides of the container by means of hard-rubber frames (grid separators). These frames also serve to separate the grids and hold the plates in correct alinement, and are designed to permit free circulation of the electrolyte. Insulation between the alternate positive and negative plates is accomplished by means of vertical hard-rubber pins running their entire length.

c. Plates.

(1) *Positive plate.* The positive plate consists of a nickel-plated steel grid holding perforated steel tubes that house the active material. This active material is inserted in the tubes in the form of nickel hydrate alternated with layers of nickel flake. It changes to an oxide of nickel after being subjected to a forming charge. The tubes, which are 4½ inches long by ¼ inch in diameter, are reinforced by equally spaced encircling seamless steel rings and are locked into position with a mechanical press. A C-type positive plate contains 45 tubes; a D-type plate contains 60 tubes.

(2) *Negative plate.* The negative plate consists of a steel grid in which the active material, iron oxide, is mounted in rectangular perforated steel pockets, which measure 3 by ½ by ⅛ inches, rather than in tubes. The steel pockets are locked in place by a hydraulic press. The negative plate used with a C-type positive plate contains 40 negative pockets. The negative plate used with a D-type positive plate contains 48 pockets.

Section III. PRINCIPLES OF OPERATION

39. Definitions

a. Ampere-Hour Capacity. The ampere-hour capacity of a nickel-iron-alkaline battery is the number of ampere-hours of current the battery will deliver continuously at its normal rate (5 hours) before its potential falls to 1 volt per cell. Because the cells of these batteries are assembled in series, the ampere-hour capacity of the battery is that of a single cell. Ampere-hour capacities are shown in table XX. The utilization of these batteries by type of equipment is shown in table XXI.

b. Voltage. The average voltage of a nickel-iron-alkaline cell is 1.2 volts at the 5-hour rate to a final voltage of 1 volt per cell. As the cells of these batteries are assembled in series, the voltage of a 30-cell battery is calculated at 36 volts (table XX).

c. Normal Rate. The normal rate of a nickel-iron-alkaline battery (table XX) is the rate of current in amperes adopted by the manufacturer as a basis for capacity rating. It is the average rate at which the battery will best accept a charge. A C5 cell, for example, will deliver 56.25 amperes continuously for a 5-hour period. In order to replace this discharge, the battery should be charged at an average of normal rate. This rate would not necessarily have to be held constant but could start as high as 93 amperes and finish as low as 37 amperes, depending upon the charging method used. These rates, however, should average approximately 56 amperes over the complete charging period.

Table XX. Nickel-Iron-Alkaline Storage Battery Capacities
(5-hour rate)

Type of cell	Ampere-hour capacity	Normal rate	Voltage	Kilowatt-hour capacity	Watt hours per cell
C5	281	56.25	36	10.12	337
C8	450	90	36	16.2	540
D8	600	120	36	21.6	720

Table XXI. Utilization of Nickel-Iron-Alkaline Storage Batteries

Item	Battery		
	30C5	30C8	30D8
Truck, fork, electric, 2,000-lb., 130-in. lift.	X		
Truck, fork, electric, 4,000-lb., 144-in. lift.		X	
Truck, fork, electric, 6,000-lb., 168-in. lift.			X
Tractor, warehouse, electric, 2,000-lb., drawbar pull.		X	
Tractor, warehouse, electric, 4,000-lb., drawbar pull.			X
Crane, warehouse, electric, 6,000-lb. capacity.		X	

40. Theory of Operation

In theory, the operation of a nickel-iron-alkaline battery, like that of a lead-acid storage battery, is based on the fact that chemical energy can be converted into electrical energy and that electricity can, under certain circumstances, be contained in chemicals. When the battery is connected to a charger and electricity is passed through the electrolyte-filled cells, oxygen is taken from the negative plates and added to the positive plates (fig. 38). When the battery is placed in operation (disconnected from the charger), the chemical changes that occurred during charging reverse themselves, and oxygen is taken from the positive plates and added to the negative. This electrochemical reaction causes the electrical energy to be dispersed in the form of direct current. Thus, the cells of the battery store chemical energy, not electricity.

41. Operating Cycle

The operation of a nickel-iron-alkaline storage battery is cyclic, consisting of a discharging action that must be followed by a charging action. The service life of a battery is determined by the number of operating cycles per year. For maximum service life, it is recommended that the battery is restricted to 300 cycles annually. The time required to recover (charge) a completely discharged nickel-iron-alkaline battery is 6 to 7 hours. This factor must be regarded as the constant element in the service cycle. Though the battery may be allowed to remain discharged or in any state

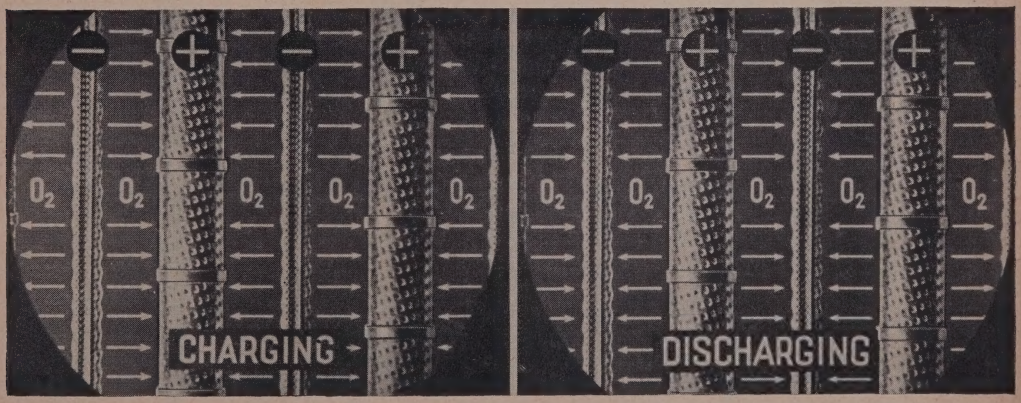


Figure 38. Charge and discharge action.

of charge indefinitely without harm, it should always be charged immediately before the next period of operation.

a. Discharging Action. On discharge (fig. 39), the electrolyte breaks down into its basic components, hydroxide (OH) and potassium (K). The potassium reacts with water and with the oxygen from nickel oxide in the positive plate to form more potassium hydroxide and a lower oxide of nickel. The hydroxide reacts with the iron in the negative plate to form iron oxide and water. Thus, on discharge, the negative plate oxidizes from pure iron (Fe) to iron oxide (FeO) in direct proportion to the reduction of nickel oxide at the positive plate.

b. Charging Action. On charge (fig. 39), the electrochemical reaction is reversed. The positive plate is oxidized and the iron oxide at the negative plate is reduced. During charge and discharge, therefore, the electrolyte serves merely as the conductor of oxygen and its density is only slightly affected.

42. Effect of Temperature on the Operating Cycle

a. Low-Temperature Effect. Low temperatures will not freeze the electrolyte used in a nickel-iron-alkaline battery at any state of charge. However, low temperatures do retard chemical reactions that take place within the battery. Because of this, the capacity of a battery to produce a given voltage at a given discharge rate is reduced during low-temperature operation. Normally, when a truck-mounted battery is operated in cold areas, the battery will generate sufficient heat during service to maintain electrolyte temperature within a satisfactory range. The insulating effect of the battery compartment is also a factor. Thus, for prolonged operation at low temperatures, the ventilating openings underneath the battery compartment should be closed to make full use of the insulating effect of the compartment.

b. High-Temperature Effect. Permanent damage to a nickel-iron-alkaline battery will result if the battery is operated at temperatures above 115° F., or if operated with a low electrolyte level resulting from the increased vaporization of water from the electrolyte. To avoid the possibility of such damage, a battery that operates in extremely high temperatures should be given a chance to cool between periods of service, and the electrolyte level should be checked frequently. As preventive measures, ventilate and cool the battery as much as possible, and add distilled water as necessary to keep the electrolyte at correct operating level. Do not add water during or after a charge.

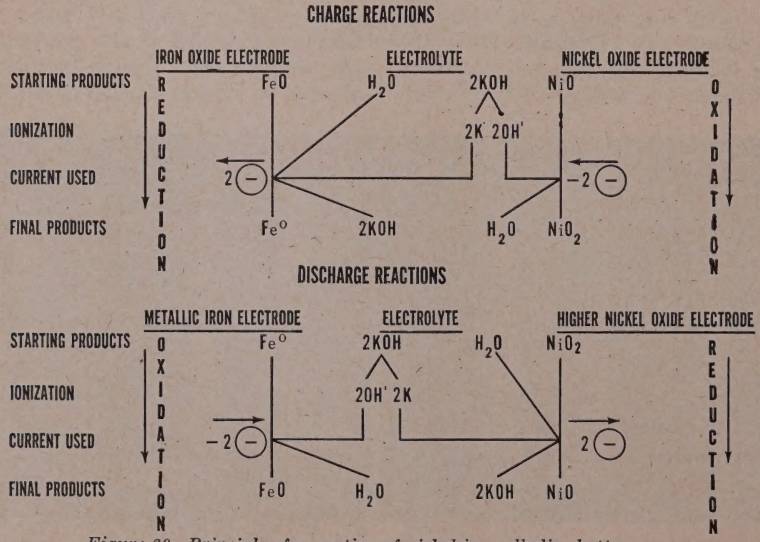


Figure 39. Principle of operation of nickel-iron-alkaline battery.

CHAPTER 6

USE AND MAINTENANCE

Section I. PREPARATION FOR USE

43. Establishing Requirements

The number of batteries in service depends primarily upon the number of 8-hour shifts in effect. Normally for operation on a single-shift basis, the number of batteries required will be the same as the number of trucks, and the batteries need not be removed from the trucks for charging. A good rule to remember is that one cycle per day gives the best results regardless of the number of shifts involved, and in setting up a work routine the most important factor is to time charging so that it will be completed just before the daily working period of the battery.

44. Uncrating and Unpacking

a. Inspect battery crate on delivery for damage. Report damage to the superior officer in charge.

b. Make certain that crate is right side up (with skid mounts resting on floor).

c. Use a forklift truck or crane of at least 3,000-pound capacity to remove the crated battery from the truck or railroad car. If a crane is employed, be sure that sling placed around crate is secured against bottom of skid and not around skid mounts.

d. Move crated battery from vehicle on which it was shipped to uncrating area.

e. Lower crated battery to floor and remove forklift fingers or crane sling.

f. Cut wire band around crate with wire-cutters.

g. With screwdriver, pry off staple that locks wire band to top of box.

h. Using a clawhammer, remove nails from the boards that secure both sides of the crate to the skid mount.

i. When crate is freed from skid mounts, lift crate off battery.

j. Inspect battery for damage and report any irregularities to the superior officer in charge.

k. Attach two chains from a spreader bar to both ends of the battery cradle and lift battery from skid mounts.

Caution: Enough tension must be maintained by the spreader bar on the chains at all times, so that they do not touch the terminals of the battery and cause a short circuit.

45. Preparing Batteries for Use

a. Discharged and Short-Circuited Batteries. New nickel-iron-alkaline batteries are normally received discharged and short-circuited. To prepare these batteries for use, proceed as follows:

(1) Remove shorting wires from cell terminals.

(2) Connect tray-to-tray jumpers (provided with each battery) as follows:

(*a*) Check taper of lugs on ends of jumpers to see that they correspond with taper on poles of cells.

(*b*) Remove any oil, grease, or other dirt from lugs and poles, using clean cloth or No. .00 sandpaper if necessary. Do not use file or other cutting tool.

(*c*) Slip jumper into place (fig. 40). If jumper does not fit poles exactly, bend as much as required (fig. 41). Do not force or hammer jumper into position.

(*d*) Grease pole threads slightly (fig. 42).

(*e*) Apply and tighten pole nuts with pole nut wrench (fig. 43).

(3) Check level of electrolyte (par. 54*b*) and add distilled water if necessary.

(4) Charge battery at normal rate (par. 39*c*) for 15 hours. After battery has been charging for 15 or 20 minutes, shut off charger and disconnect battery from charging equipment. Feel jumpers to see if they are hot. If so, jumpers may be too loose or poles may not have been thoroughly cleaned. If loose, tighten jumpers; if jumpers are tight, remove the jumpers (fig. 44) with lug jack (app. III) and examine poles carefully for dirt or grease. Reconnect battery to charger, start charger, and continue for a 15-hour charge.

b. Charged Batteries. Batteries intended for service within 30 days, or batteries removed from service for shipment, may be received charged. To prepare these batteries for service, proceed as follows:

(1) Check level of electrolyte to make certain none was lost during shipment.

(2) If evidence of spillage is detected, replace lost electrolyte with standard refill solution (par. 57*d*).

(3) Apply tray-to-tray jumpers and terminal leads.

(4) Charge battery at normal rate (par. 39*c*) for 2 hours.

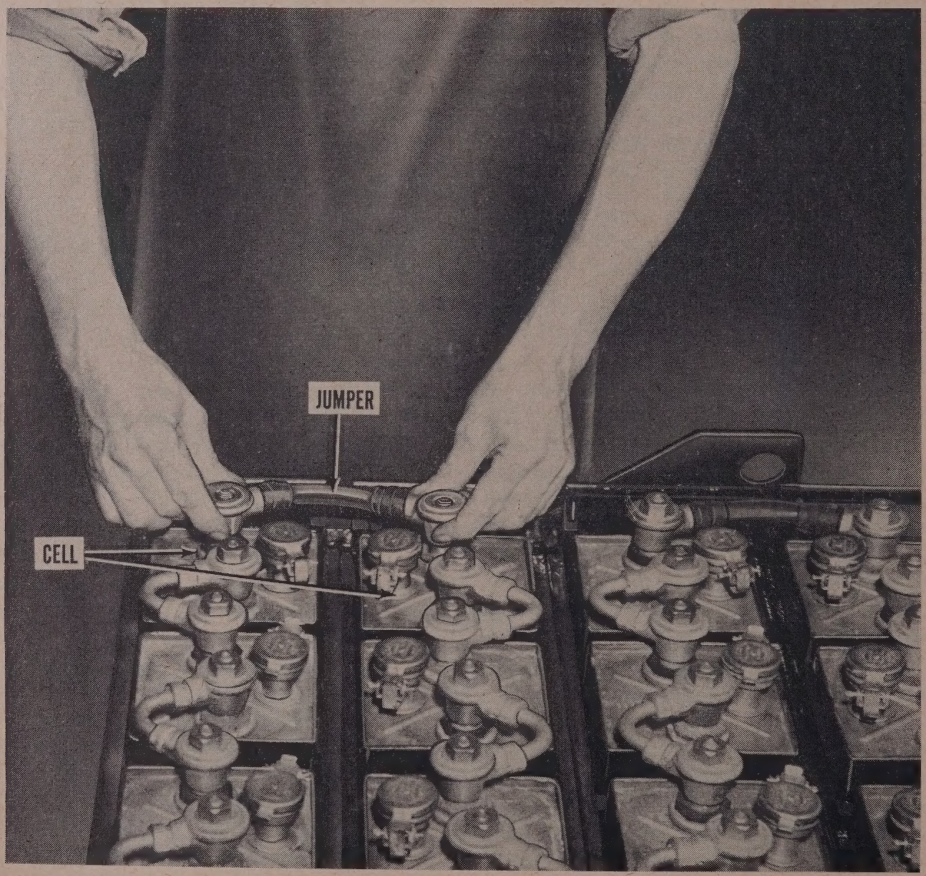


Figure 40. Placing tray-to-tray jumper in position on nickel-iron-alkaline battery.

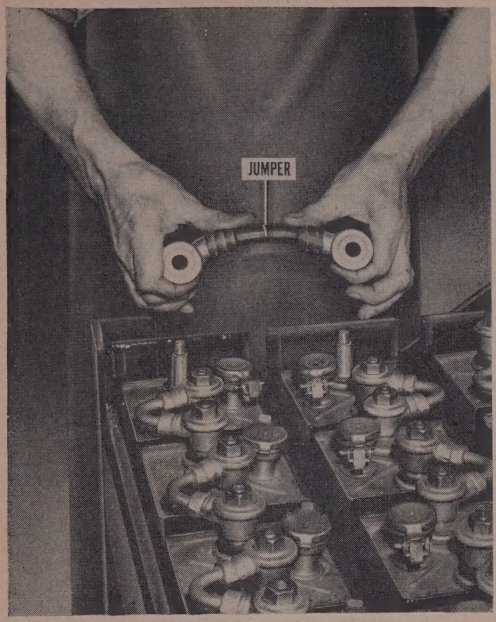


Figure 41. Bending tray-to-tray jumper.

Figure 43. Tightening pole nuts.

Figure 42. Greasing pole threads.

Figure 44. Removing jumper lug with lug jack.

46. General

Charging is the process of passing direct current through the cells of a battery in a direction opposite to that of discharge for as long as needed to replace the number of ampere-hours taken from the battery during service.

47. Charging Equipment

Approved charging equipment provides completely automatic control of charging. Charging rates, length of charge, and discontinuance of charge are accomplished by means of voltage relays and timers or ampere-hour meters built into or used in conjunction with charging equipment. Only direct current can be used for charging. If alternating current is available, it must be converted to direct current by means of approved motor generators or rectifiers.

a. Motor Generator. The standard motor-generator charger (Federal Specification W–C–256a) is the combination- or conversion-type that can be used with either 18-cell lead-acid or 30-cell nickel-iron-alkaline storage batteries. It operates on a 220-volt, 60-cycle, 3-phase power line and may be equipped with single or multiple charging circuits.

b. Rectifier. The standard rectifier is the charger, storage battery, combination-type, 18-cell lead-acid or 30-cell nickel-iron-alkaline storage battery, 220-volt, 60-cycle, 3-phase, single-circuit, metallic rectifier charger (Quartermaster Stock No. 17–C–8785–75).

48. General Charging Principles

The charging of a nickel-iron-alkaline battery is characterized by an average (constant) or normal rate (par. 39*c*). Although start and finish rates are involved, these rates are so designed that they average over the charging period the normal rate established by the manufacturer. Thus, the battery is not charged at the normal rate, but at a start and finish rate that will average the normal rate.

Note. Starting rates are never more than 125 to 165 percent of the normal rate, depending upon the method used; finish rates are never less than 65 to 80 percent of the normal rate, depending upon the method used.

a. Establishing Polarity. Special care must be taken to see that proper polarity is maintained when the battery is attached to the charger. The positive terminal of the battery connector must be connected to the positive terminal of the charger and the negative terminal of the battery connector to the negative terminal of the charger. Accidentally reversing the polarity will not result in permanent damage to the battery. Corrective measures should be taken immediately, however, to insure proper operation.

b. Controlling Gassing. Gassing is a phenomenon that takes place while a battery is on charge. It is evidenced by bubbling of the electrolyte. The gases liberated are oxygen and hydrogen. The point at which gassing begins is determined by voltage, but the amount of gas depends upon the portion of the current (charging amperage) that is not absorbed by the battery. Gassing in a nickel-iron-alkaline battery occurs throughout the entire period of charge.

49. Charging Methods

a. Modified Constant Voltage. The modified constant voltage (potential) method is normally used for charging nickel-iron-alkaline storage batteries with motor-generator charging equipment when a bus voltage of at least 1.84 volts per cell is available. The charging rate in amperes starts out at any value not higher than 1.65 percent of normal and tapers to a finish rate not less than 65 percent of normal. An ampere-hour meter is used to terminate charge. This method is most satisfactory where charging two or more batteries is parallel from a single direct current power source.

b. Constant Current. The constant current method is normally used for charging nickel-iron-alkaline storage batteries with a single-circuit rectifier. The rectifier should have voltage and ampere characteristics that result in charging rates that start at not more than 125 percent of normal and finish at not less than 80 percent of normal. This method is most satisfactory when charging single batteries.

50. Charge-Control Equipment

The charge-control equipment required for nickel-iron-alkaline batteries includes charge test forks and charge indicator tables.

a. Charge Test Fork. A charge test fork is an instrument used to measure the voltage of a pilot cell discharging through a fixed resistance. When used in conjunction with a charge indicator table, a charge test fork indicates the required charging rate and time for charging a nickel-iron-alkaline battery. Use a type II charge test fork (fig. 45) with C5, C8, and D8 cells. Always allow the battery to stand for approximately one-half hour after discharge before taking a charge test fork reading. Do not use the test fork to determine the state of charge following a charge; it is designed only to indicate the input needed to recharge a battery after discharge. The test fork should not be used with batteries in standby service or in storage.

Note. The charge required by a nickel-iron-alkaline battery must be determined with a test fork. It cannot be determined by the specific gravity of the electrolyte.

b. Charge Indicator Tables. Charge indicator tables are used to translate charge test fork readings into ampere-hour meter or time clock settings for charging a nickel-iron-alkaline battery. Because separate charge tables are published for each type cell, special care must be taken to make certain that the correct table is used. Charge indicator tables to be used with type II test fork for C5, C8, and D8 cells appear as appendixes V through VII.

Figure 45. Charge test fork.

51. Charging Procedure

Proceed as follows to charge a nickel-iron-alkaline battery by the constant current method on a rectifier-type charger (Quartermaster Stock No. 17–C–8787–75) :

a. If charger has not been previously set for nickel-iron-alkaline batteries, open charger door and move EDISON—LEAD ACID switch to EDISON position.

b. Start charger and observe charging rate. Shut charger off and adjust rate by moving adjusting bumper bar on rate control panel to obtain the starting rate shown in table XXII. A discharged C5 battery, for example, should be set at 70 amperes.

c. Take charge test fork reading of battery and set timer to hours and minutes specified on appropriate charge indicator table for corresponding test fork reading. At a test fork reading of 1.03, for example, a C5 battery should be set for 5 hours and 40 minutes.

d. Start charger. Timer will operate throughout entire charging period.

Table XXII. Charging Rates for Nickel-Iron-Alkaline Batteries (Rectifier-Type Charger)

Type of cell	Ampere-hour capacity	Normal rate	Starting rate	Finish rate
C5_____	281	56.25	70	45
C8_____	450	90	113	72
D8_____	600	120	150	96

52. Types of Charge

a. Routine Charge. A routine charge is a charge administered at the normal rate before the beginning of the next scheduled period of service to restore the current expended during discharge. A routine charge is part of the battery cycle, which consists of a charge and discharge.

b. Booster Charge. A booster charge consists of charging the battery for a short time during

brief periods of inactivity. This charge must be used only as an emergency measure when it is desired to obtain more than a usual day's work from a battery. To prevent the possibility of damage to charging equipment, do not use a booster charge rate higher than the regular charging rate.

c. Equalizing Charge. An equalizing charge of the type described in paragraph 18*b* must *not* be administered to a nickel-iron-alkaline battery.

53. Charging Precautions

a. Make certain that fillercaps are kept closed during charge.

b. Make certain cell temperature does not exceed 115° F. Make certain that battery is well ventilated while charging. If possible, charge battery at temperatures below 100° F. The continued passage of charging current through a battery after it has reached a charged condition, is not harmful to a nickel-iron-alkaline battery as long as cell temperatures remain below 115° F. and there is not sufficient dissipation of water to lower the level of the electrolyte.

c. Do not interchange hydrometers, test forks, containers, or other devices used in connection with lead-acid batteries with those used in conjunction with nickel-iron-alkaline batteries.

d. Do not place a tool or other piece of metal on a battery.

e. Do not smoke or light matches or bring open flame into the charging area. Take every precaution to keep electrolyte from coming in contact with clothing or skin. If electrolyte is spilled on clothing or skin or comes in contact with eyes, wash immediately in a solution of 4 percent boric acid or in generous amounts of clear water.

Section III. ROUTINE SERVICING

54. Adding Water

a. General. The addition of distilled water to battery cells is necessary to maintain the proper concentration and level of electrolyte in the cells. To determine if water is required, check the water level daily. If a battery is scheduled for charging, add water immediately before charging. Never add water during or immediately after charging.

b. Procedure.

(1) Measure the level of battery electrolyte, using the testing tube provided with the battery or a piece of ¼-inch glass tubing approximately 8 inches long on one end of which should be placed a piece of tight-fitting rubber tubing. To measure the level, insert the tube into a cell until it touches the top of the plate; then close the upper end of the tubing with the finger and withdraw the tube from the cell. Take the liquid level reading by means of the tube graduations on the testing tube (fig. 46), or measure the height of the electrolyte in the tube with a ruler.

(2) Use a 1-gallon gravity battery filler (Federal Specification W–B–177), and add distilled water until each cell is filled to its approved level. The approved level for C-type cells is 1 inch above plate tops; for D-type cells, 1¼ inches above plate tops (fig. 47(A)). Because gassing on charge creates a false level by raising the height of the solution, sometimes as much as 1 to 1½ inches (fig. 47(B)), do not check the electrolyte level with the battery on charge.

55. Measuring Specific Gravity

a. Taking Reading. The specific gravity of a nickel-iron-alkaline battery is taken to determine whether renewal of the electrolyte is necessary. *It does not indicate the state of charge of the battery.* To obtain a correct specific gravity reading, it is necessary to take an initial reading with a hydrometer, as described in paragraph 21*a*, and then correct this reading for deviations from the standard temperature (60° F.) and the normal electrolyte level (1 inch for C-type cells and 1¼ inches for D-type cells).

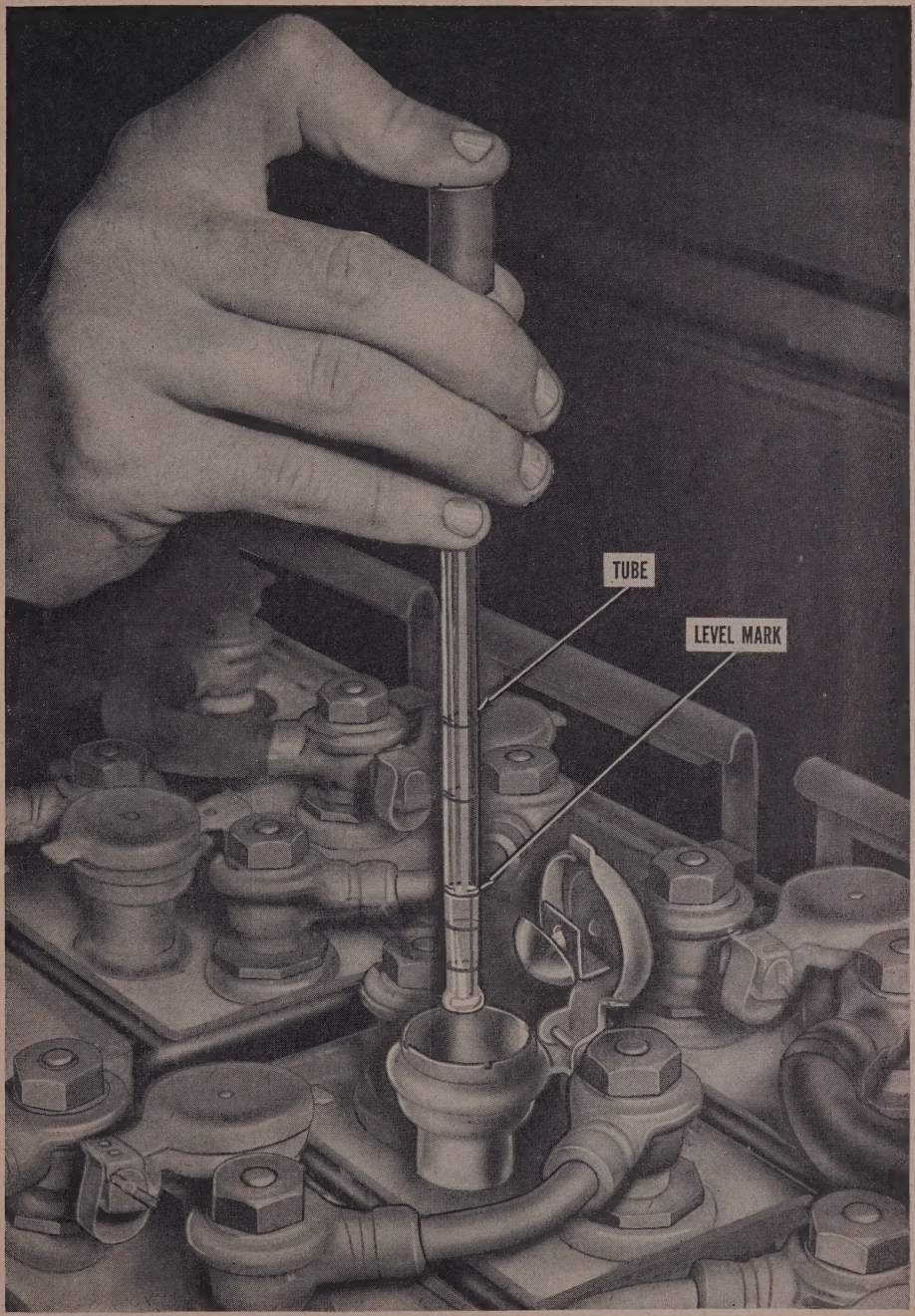
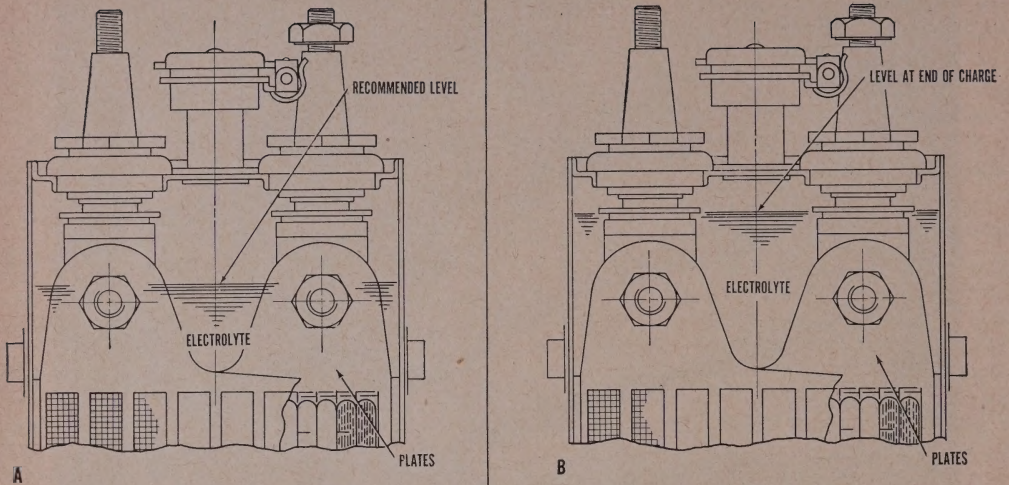


Figure 46. Determining height of electrolyte in nickel-iron-alkaline cell.



A. Normal level

B. Level raised by gassing

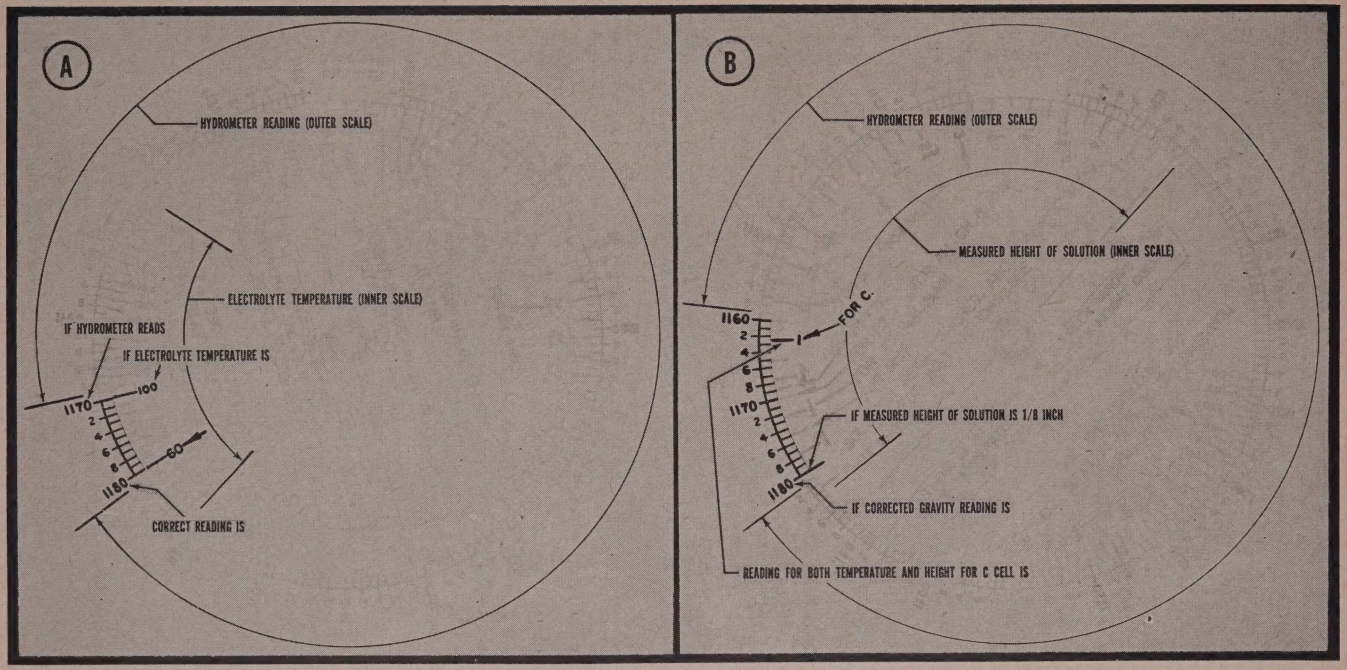
Figure 47. Recommended electrolyte level for nickel-iron-alkaline battery cell.

b. Adjusting Reading.

(1) *By calculation.* The hydrometer reading may be mathematically corrected for temperature by adding or subtracting ¼ point (.00025) specific gravity for each degree of temperature above or below 60° F. If, for example, the hydrometer reading of a C-type cell is 1.170 and cell temperature (taken with a thermometer) is 100° F., the reading corrected for temperature is 1.180, derived as follows: 1.170 + (40 × .00025) = 1.180 or 1.170 + .010 = 1.180. After the temperature correction has been made, it will be necessary to adjust the hydrometer reading for electrolyte level by adding or subtracting 20 points (.020) specific gravity per inch for any distance above or below the normal level. If, using the example above, the corrected reading of a C-type cell for temperature is 1.180 and the height of the electrolyte (taken with a testing tube) is ⅛ inch above plate tops (⅞ inch below the normal 1 inch level) the corrected reading for both temperature and electrolyte level would be 1.162½, derived as follows: 1.180 — (⅞ × 0.20) = 1.162½ or 1.180 — .0175 = 1.1625.

Note. When expressing specific gravity of a storage battery, it is common practice to disregard the decimal point in the reading and consider the last digit as representing one point of specific gravity. Thus, in the mathematical method of adjusting the hydrometer reading, it is possible to substitute the fraction ¼ for the decimal .00025, in the case of the temperature reading, and the whole number 20 for the fraction .020 in the electrolyte level correction as follows: 1170 + (40 × ¼) = 1180 and 1180 — (⅞ × 20) = 1162½.

(2) *By scale.* The above adjustments may be made with the aid of an electrolyte specific gravity adjusting scale (fig. 48) that may be obtained from the battery manufacturer. If, using the example above, the hydrometer reading for a C-type cell is 1.170, rotate the dial of the scale counter-



A. Temperature correction

B. Electrolyte level correction

Figure 48. Electrolyte specific gravity adjusting scale.

clockwise until the mark indicating 100° F. on the A portion of the dial is opposite the specific gravity reading of 1170 on the outer stationary scale (fig. 48A). The hydrometer reading corrected for temperature will be 1180 as indicated by the arrow opposite 60° F. on the dial. Next, rotate the dial clockwise until the mark on the B portion of the dial representing the electrolyte level of ⅛ inch is opposite the corrected specific gravity reading of 1180 as shown on the outer scale (fig. 48B). The specific gravity reading for both temperature and electrolyte height (1.162½) will be shown at the normal level mark for C-type cells (1 inch) on the inner scale.

56. Renewing Electrolyte

The electrolyte in a nickel-iron-alkaline battery must be renewed when its adjusted specific gravity falls below 1.160. This will occur only once or twice during the life of the battery when the solution becomes weakened through spillage, overwatering, gassing, evaporation, or the introduction of impurities through filler holes. To renew the electrolyte, proceed as follows, wearing rubber gloves, goggles, and a protective rubber apron:

a. Discharge the battery until voltage is down to 0.5 volts per cell (15 volts for a 30-cell battery). To do this, discharge the battery at a normal 5-hour rate through a water-barrel rheostat or other resistance. A water-barrel rheostat can be made by partially filling a used steel drum with a 1 to 3 percent solution of salt water and immersing two soft metal plates in the solution (fig. 49). Current applied at one terminal leaves the plate and passes through the water to the other. One of these plates is stationary, the other movable; and the resistance is regulated by changing the distance between them. The farther the plates are apart, the greater the resistance.

b. Disconnect tray jumpers and leads. Short circuit each tray of the battery by connecting leads to opposite terminals of end cells (fig. 50). Allow each tray to cool until electrolyte is not more than 5° above room temperature.

c. Remove one tray at a time and dump electrolyte over a floor drain. Make certain that concrete floor is available and that the floor drain is provided with iron or steel pipe fittings. Electrolyte is injurious to aluminum, wood, brass, copper, lead, or zinc. Short lengths of wood can be used to support the tray while it is being dumped.

d. Using a clean glass or enamel funnel, pour new electrolyte into cells. The electrolyte to be used is standard renewal solution, which has a specific gravity of 1.250 and which is intended for use with cells having a specific gravity of 1.160 to 1.170 when dumped. Do not use any solution other than standard renewal solution. Quantities of solution to be used are shown in table XXIII. Do not rinse cells with water. Do not shake cells. Do not allow cells to remain without solution for any extended period of time. Fill exactly to prescribed height. Do not overfill.

e. Allow battery to stand for about ½ hour. Check level of electrolyte in each cell and add more electrolyte if required.

f. Charge battery at normal rate for 15 hours.

Table XXIII. Renewal Solution Requirements, Nickel-Iron-Alkaline Batteries

Type of cell	Renewal solution required
	Pounds per cell
C5	5.51
C8	8.65
D8	11.48

57. Replacing Electrolyte

Electrolyte must be replaced when some of the original solution has been lost through spillage. To replace spilled electrolyte, use standard refill electrolyte solution, which has a specific gravity of 1.215. If this solution is not available, use standard renewal solution diluted with distilled water to a specific gravity of 1.215 at 60° F. or, by volume, 5 parts of solution to 1 part of water. Add solution until proper level is reached, and discharge the battery as described in *a* below; then charge at normal rate for 15 hours. If no solution is

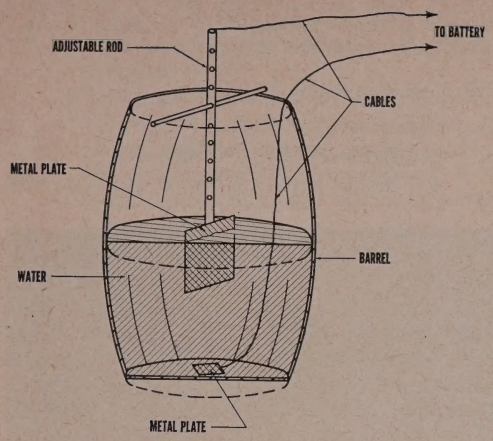


Figure 49. Water-barrel rheostat.

available, one of the following corrective measures may be adopted:

a. If solution left in cell is still above plate tops or can be seen with a flashlight, add distilled water and continue battery in service.

b. If solution is below plate tops or cannot be seen with a flashlight, remove battery from service until solution is available. In the meantime, keep fillercaps tightly closed.

58. Cycling

Cycling is a process used to correct a battery sluggishness or to correct the failure of a battery to deliver the full extent of its capacity because of intermittent or irregular service. To cycle a battery, proceed as follows:

a. Discharge the battery at its normal rate until its potential falls to 15 volts (0.5 volts per cell). Use voltmeter to determine voltage.

b. Short circuit the battery and allow to stand until temperature falls to 5° above room temperature.

c. Check level of electrolyte and add distilled water as necessary to bring electrolyte to correct level in each cell.

d. Charge battery at normal rate for 15 hours.

e. Immediately discharge at normal rate and keep a record of the time until the potential

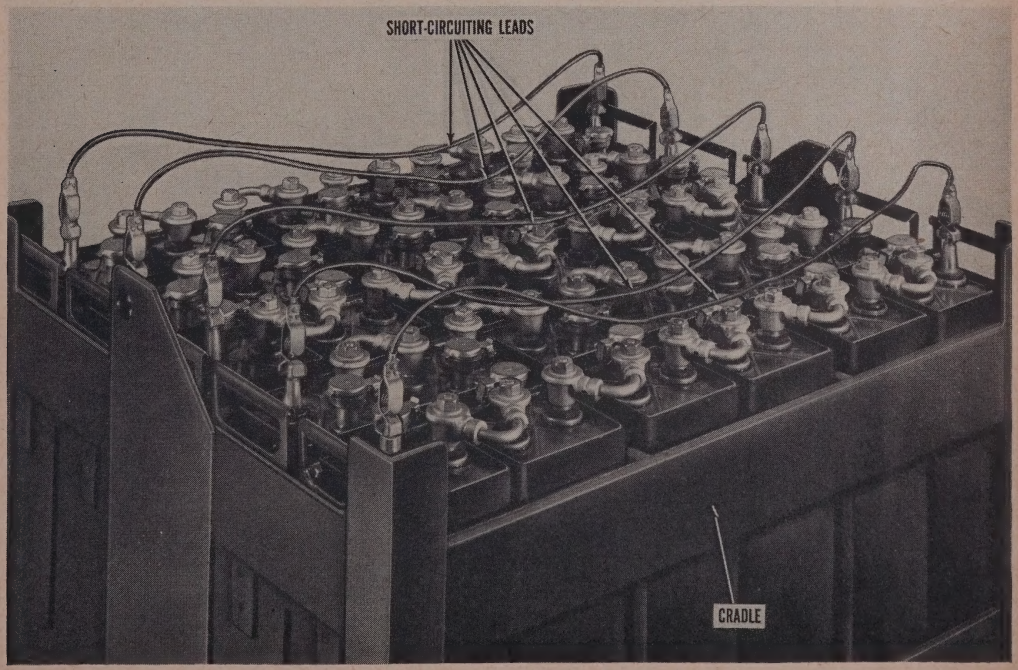


Figure 50. Short-circuited nickel-iron-alkaline battery.

(voltage) of the battery drops to 30 volts (1 volt per cell). Use voltmeter to determine voltage. A discharge at the normal rate for 5 hours before the equivalent of 1.00 volt per cell is reached indicates full rated capacity. If less capacity is indicated, continue to cycle several more times. If no improvement is noted, report to designated person in authority.

Note. Keep electrolyte below 115° F. except while battery is short circuited. Take voltmeter readings while current is flowing at normal rate only.

59. Cleaning and Painting

a. Cleaning.

(1) Remove battery from truck.

(2) Mount battery on wood planks so that

Figure 51. Cleaning nickel-iron-alkaline battery.

dirt will blow out through bottom. Make certain that fillercaps are tightly closed.

(3) Using a wet steam jet (fig. 51), blow out spaces between cells. Clean cell tops and connectors. As a personal safety measure, wear goggles.

(4) Using air blast, blow off any accumulated moisture.

(5) After cleaning, apply cell preservative and cleaning compound (app. III) to cell tops.

b. Painting. When necessary, paint cell sides and trays with a black, alkali-resistant paint (app. III).

60. Replacing Parts

Limit replacement of parts to the replacement of cell and tray connectors, gland caps, and filler-valve assemblies. Make certain that

Figure 52. Removing hinge band with jack and block.

fillercaps, hinge bands, and lid springs are in proper alinement; however, before making replacement, tighten gland caps of any cells that show leakage around the stuffing-box assembly, using a special gland cap wrench (app. III). The fillercaps are held in position by means of a hinge band that is a force-fit in the filler body. These bands may be replaced, as shown in figures 52 and 53, by the use of special hinge band removing tools listed in appendix III. In order that the proper type of cell connector or jumper may be replaced or ordered, a replacement part guide is included as appendix IV.

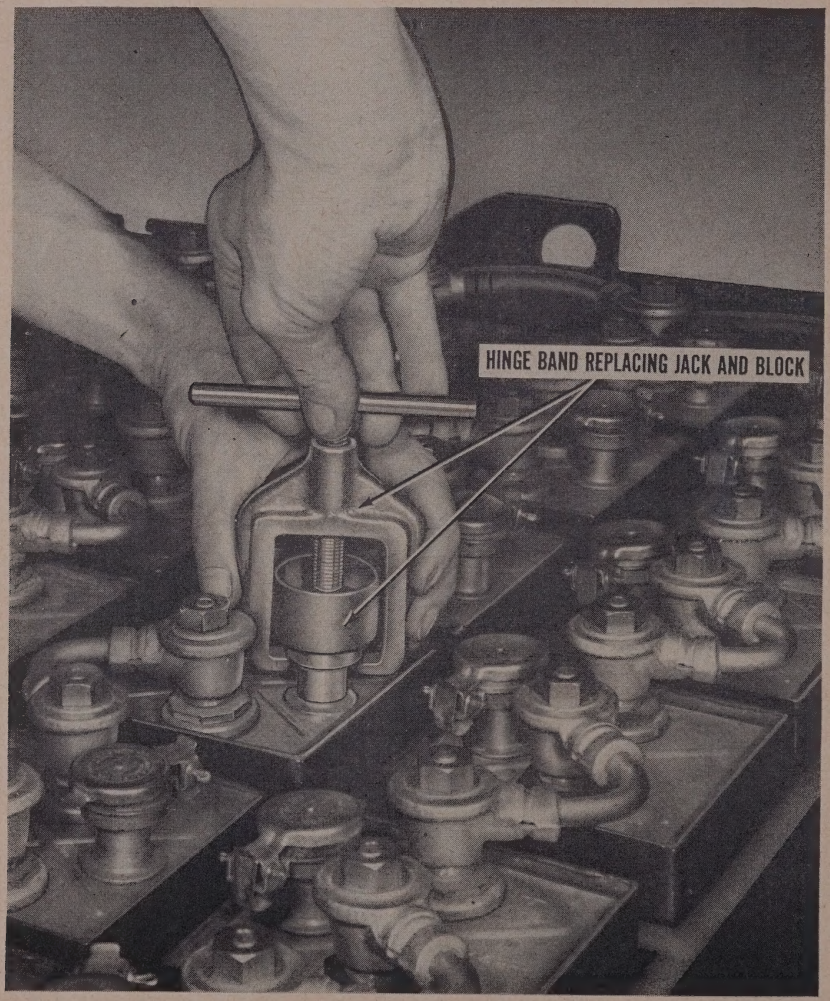


Figure 53. Replacing hinge band with jack and block.

CHAPTER 7
STORAGE AND SHIPMENT

61. Depot Procedures

Prepare battery for storage by discharging at normal rate to 0.5 volts per cell. Short circuit each tray by connecting a wire from the positive terminal cell to the negative terminal cell. Check electrolyte to see that it is at proper level. Make certain that fillercaps are closed. Store battery in a clean, dry place. No further maintenance is required during storage or shipment. Approximate shipping weights and cubages appear in table XXIV.

62. Using Organization Procedures

If battery is to be out of service for a period of more than 6 months, discharge, short circuit, and store the battery as described above. If battery is to be stored for less than 6 months, discharge at normal rate to 1.0 volt per cell. No further maintenance is required during shipment or storage.

63. Removal of Battery From Storage

Remove short-circuiting wires from terminal cells; add distilled water, if necessary, to raise electrolyte to prescribed level; and charge battery for 15 hours at normal rate. A battery removed from storage should deliver full capacity when placed in service.

Table XXIV. Approximate Shipping Specifications for Nickel-Iron-Alkaline Batteries

Type of battery	Shipping weight	Shipping cubage
	Pounds	Cubic feet
C5	1090	24
C8	1585	31
D8	2100	44

APPENDIX I
REFERENCES

1. Indexes

SR 110–1–1 Index of Army Motion Pictures and Film Strips.

SR 312–20-series.

2. Maintenance

SR–700–45–5 Unsatisfactory Equipment Report.

SR 745–45–5 Report of Damaged or Improper Shipment.

TB ORD 324 Nickel-Iron-Alkaline Storage Batteries; Operation, Maintenance, and Storage.

TM 11–5539 Storage Battery BB–401/U.

TM 9–2857 Storage Batteries: Lead-Acid Type.

3. Nomenclature

SR 320–5–1 Dictionary of United States Army Terms.

APPENDIX II

SUGGESTED TOOLS AND EQUIPMENT FOR MAINTENANCE OF LEAD-ACID STORAGE BATTERIES

Item	Part number		
	C & D batteries	Exide batteries	Gould batteries
Button mold	Not required.	Not required.	P–77015.
Carbon burning outfit	*RE–185A.	*20104.	*Z–614A.
Cell lift nut	RE–147.	Not required.	Not required.
Cell lift nut and post threader	RE–148.	Not required.	Not required.
Connector splicing mold			*ED–2137.
Glass caulking cord	Not required.	CSE 1.5/2.	Not required.
Hydrometer	*PL–515.	*13142.	*Z–38A.
Jar holddown clips	*RE–149.	*32345.	*Z–1445.
Lead insert mold	Not required.	Not required.	P–77016.
Negative loop nut	Not required.	31346.	Not required.
Positive loop nut	Not required.	31345.	Not required.
Post mold	Not required.	Not required.	P–77013.
Post trimmer	Not required.	Not required.	Z–1265.
Sealing compound (oil asphalt)	*PS–105.	*206.	*76003.
Seal nut wrench	RE–135	23324.	Not required.
Separator inserter		*SB27465.	*Z–1700.

* May be used on all three types.

APPENDIX III

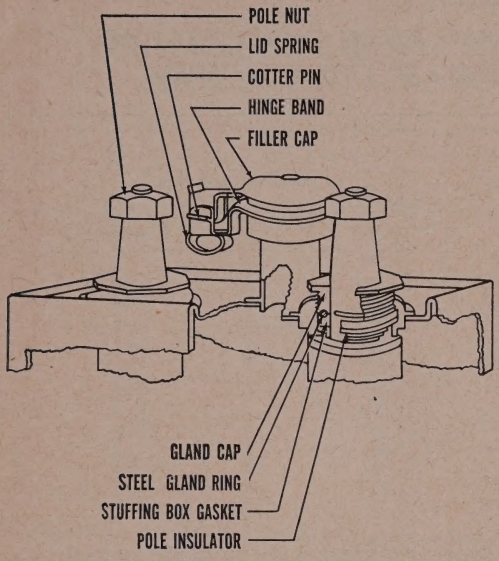
TOOLS AND EQUIPMENT FOR MAINTENANCE OF NICKEL-IRON-ALKALINE STORAGE BATTERIES

Item *	Quantity	Use
Pole nut wrench	1 per battery	To tighten or loosen pole nuts.
Lug disconnecting jack	1 per battery	To disconnect lugs.
Gland cap wrench	1 per battery	To tighten or remove gland caps.
Pole threading die and dieholder	As required	To restore damaged pole threads.
Hinge band removing jack and block	As required	To remove hinge bands.
Hinge band replacing jack and block	As required	To replace hinge bands.
Hydrometer (range 1.120 to 1.280)	As required	To take specific gravity readings.
Test tube	1 per battery	To determine height of electrolyte.
Equalizer	As required	To adjust electrolyte height.
Charge test fork, type II	As required	To determine state of charge in C5, C8, and D8 cells.
Esbalite** (black, alkali-resistant paint)	2.55 gallons per C5 battery 3.24 gallons per C8 battery 4.17 gallons per D8 battery	To paint trays, sides, and bottoms of cells.
Esbaline** (cell preservative and cleaning compound).	As required *Note.* 1 quart is sufficient for 600 C- or D-type cells.	To coat cell tops.
Electric filling outfit:		
Types DA and DD (with adapter)	As required for C-type cells.	To water batteries.
Type DD	As required for D-type cells	

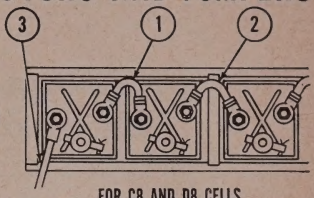
* When ordering any of the above items, always specify type and size of cell.

** Registered United States Patent Office.

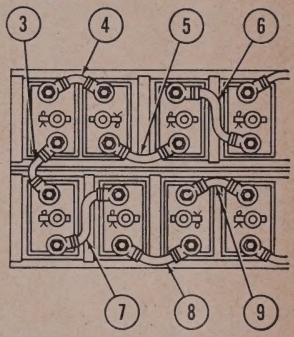
GUIDE TO CELL REPLACEMENT PARTS, CONNECTORS AND JUMPERS



1 REGULAR CONNECTOR
2 OP (OVER-PARTITION) CONNECTOR
3 JUMPER
4 REGULAR SHORT CONNECTOR
5 OP (OVER-PARTITION) LONG CONNECTOR
6 RH (RIGHT-HAND) CROSS CONNECTOR
7 LH (LEFT-HAND) CROSS CONNECTOR
8 OP (OVER-PARTITION) SHORT CONNECTOR
9 REGULAR LONG CONNECTOR



FOR C8 AND D8 CELLS

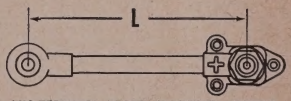


FOR C5 CELLS

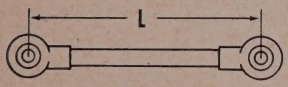
WHEN ORDERING CELL PARTS, SPECIFY NAME, TYPE AND SIZE OF CELL, AND QUANTITY NEEDED.

WHEN ORDERING CONNECTORS, SPECIFY TYPE OF CONNECTOR, TYPE AND SIZE OF CELL, AND QUANTITY REQUIRED.

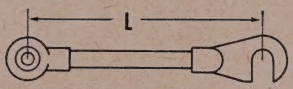
WHEN ORDERING JUMPERS, SPECIFY TYPE OF JUMPER, LENGTH (L) TO NEAREST 1/4 INCH, TYPE AND SIZE OF CELL, AND QUANTITY REQUIRED.



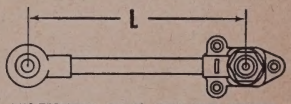
LUG-TERMINAL PLATE, (POSITIVE) JUMPER



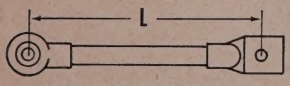
LUG-LUG JUMPER



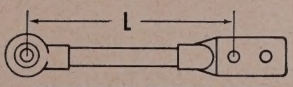
LUG-HOOK JUMPER



LUG-TERMINAL PLATE, (NEGATIVE) JUMPER



LUG-FLAT PLATE, (ONE-HOLE) JUMPER



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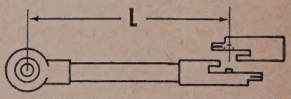
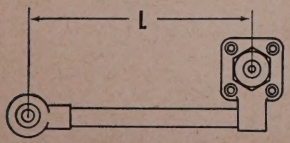
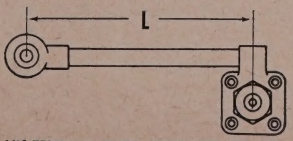


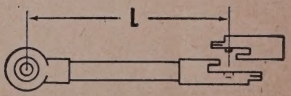
LUG-HAND CONNECTOR, (MALE) JUMPER



LUG-TERMINAL PLATE, (RIGHT-HAND) JUMPER



LUG-TERMINAL PLATE, (LEFT-HAND) JUMPER



LUG-HAND CONNECTOR, (FEMALE) JUMPER

APPENDIX V

CHARGE-INDICATOR TABLE (FOR USE WITH EDISON CHARGE TEST FORK, TYPE II, TO CONTROL THE CHARGING OF TYPE C5 BATTERIES)

Test-fork reading	Ampere-hour meter setting	Time at 56.25 amperes	
		Hours	Minutes
1.14	60	1	20
1.12	85	2	0
1.10	115	2	30
1.09	140	3	10
1.08	170	3	50
1.07	200	4	30
1.05	225	5	0
1.03	255	5	40
1.00	280	6	20
Below 1.00	315	7	0

Note 1. If test fork reading is between any two of the values indicated in this chart, use the lower one.

Note 2. Allow battery to stand at least ½ hour after discharge to permit the cells to stabilize. Push prong of fork over contact pieces and read the meter after 10 seconds. Set panel ampere-hour meter for corresponding value shown in table. The excess charge over discharge adjustment of the ampere-hour meter should be set at 25 percent.

Note 3. Keep contact pieces and prongs of fork clean.

APPENDIX VI

CHARGE-INDICATOR TABLE (FOR USE WITH EDISON CHARGE TEST FORK, TYPE II, TO CONTROL THE CHARGING OF TYPE C8 BATTERIES)

Test-fork reading	Ampere-hour meter setting	Time at 90 amperes	
		Hours	Minutes
1.23	90	1	20
1.21	135	2	00
1.18	180	2	30
1.17	225	3	10
1.15	270	3	50
1.14	315	4	30
1.12	360	5	00
1.10	405	5	40
1.05	450	6	20
Below 1.05	500	7	00

Note 1. If test fork reading is between any two of the values indicated in this chart, use the lower one.

Note 2. Allow battery to stand at least ½ hour after discharge to permit the cells to stabliize. Push prong of fork over contact pieces and read the meter after 10 seconds. Set panel ampere-hour meter for corresponding value shown in table. The excess charge over discharge adjustment of the ampere-hour meter should be set at 25 percent.

Note 3. Keep contact pieces and prongs of fork clean.

APPENDIX VII

CHARGE-INDICATOR TABLE (FOR USE WITH EDISON CHARGE TEST FORK, TYPE II, TO CONTROL THE CHARGING OF TYPE D8 BATTERIES)

Test-fork reading	Ampere-hour meter setting	Time at 120 amperes	
		Hours	Minutes
1.25	120	1	20
1.23	180	2	00
1.21	240	2	30
1.20	300	3	10
1.18	360	3	50
1.17	420	4	30
1.15	480	5	00
1.13	540	5	40
1.09	600	6	20
Below 1.09	670	7	00

Note 1. If test fork reading is between any two of the values indicated in this chart, use the lower one.

Note 2. Allow battery to stand at least ½ hour after discharge to permit the cells to stabilize. Push prong of fork over contact pieces and read the meter after 10 seconds. Set panel ampere-hour meter for corresponding value shown in table. The excess charge over discharge adjustment of the ampere-hour meter should be set at 25 percent.

Note 3. Keep contact pieces and prongs of fork clean.

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[AG 412.42 (4 Jun 54)]

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For explanation of abbreviations used, see SR 320–50–1.

U. S. GOVERNMENT PRINTING OFFICE: 1954—270620

TM10-1690A-3